Designing Tabletop Applications for Collaboration in Non-Collaborative Learning Tasks in the Classroom: Learning Persuasive Writing

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For Jane.

Abstract

Learning in a face to face collaborative setting can have many benefits, such as leveraging differing peer proficiency to obtain an outcome not reachable by the individuals involved. Including expertise provided by teachers decreases this gap between potential and current ability, while also providing opportunity for the expert to impart timely and appropriate assistance to the learners. In the fields of Human Computer Interaction and Educational Technology, digital tabletops have come to the fore as a medium for facilitating small groups of collaborative learners, and suitable applications can provide at least some of the support that the teacher's expertise would in the learning process. Previously, most explorations in this area have concentrated on learning tasks that are already collaborative in nature, and have focused on single group deployments, and usually in controlled settings such as a research lab.

This thesis focuses on two main aims: (i) investigating the design of such applications, and how learning tasks not normally considered collaborative, such as Persuasive Extended Writing, might be adapted to a digital tabletop mediated collaborative learning task; and (ii), how to expand this application from a single group to a classroom scenario, and overcoming all the challenges that an "in the wild" deployment of this kind might entail. A review of previous literature on collaborative learning and collaborative learning technology inform a learner centred design process of an application for the collaborative learning of Persuasive Extended Writing. This design process was conducted with three groups of three learners aged 13 – 15 in the lab. Based on this investigation of the literature around collaborative learning, there is a potential learning impact from allowing collaboration in a usually non-collaborative learning setting. The application incorporates factors designed to elicit collaborative behaviours, such as visuospatial representations and decision points. The work then sets about identifying and evaluating these collaborative behaviours, with a view that they are potentially in line with this ultimate learning goal.

The Collocated Collaborative Writing application (CCW) is deployed and evaluated in an “in the wild” classroom setting. This involved two studies in real classrooms in schools, with eight digital tabletops allowing for a class-wide deployment. In the first study, participants were students of mixed ability, year 8 (aged 13-14), studying English, Geography and History. In the second study, participants were mixed ability year 8 students (aged 13-14) studying English. Studies were facilitated by teachers who had created the material for the studies based on their current teaching and curriculum. The process identified the issues and challenges involved in this kind of “in the wild” deployment. The lessons learned from this process about the differing expectations of the stakeholders involved in the first study informed the second deployment. A combination of addressing the issues directly, forming a more equal partnership with the school and teacher, and differences in culture between the schools lead to a study in which the collaborative writing application is evaluated.

There are two main contributions of this work. Firstly, a set of design guidelines derived from lessons learned during the design process. Their intention is to assist in the process of making a normally non-collaborative learning task into a collaborative one, by exploiting affordances of the technology. The second contribution comes from lessons learned from two “in the wild” classroom studies. It outlines a deeper understanding of how this kind of application can be extended to the classroom by gaining insight into expectations of the parties involved, understanding the culture of the school and making the process a partnership rather than an imposition. The work also evaluated the Collaborative Writing Application in terms of the type and quality of the collaborative behaviours of the participants, and how they changed over time, as well as the adoption of the technology by the teacher, eventually being seen as a tool for their own agenda rather than an external element in the classroom.

Acknowledgments

The completion of this thesis would not have been possible without the support and contributions of a number of people. These include my supervisory committee; Madeline Balaam, David Leat and Patrick Olivier. A special mention must be made of Ahmed Kharrufa, who acted in many respects as the fourth supervisor of the work, during both the technical aspects of the work (such as software development) and the overall understanding of the work.

The classroom studies would not have been possible without the excellent collaboration of the schools and teachers. Longbenton School and St. Thomas More School provided a platform for the bulk of the work, and special thanks should go to the teachers involved; Jon Foley, Ann Westgarth, Matt Pringle, Graeme Ferguson, Kat Davis and Elizabeth Doyle. The studies and data collection would also not have been possible without the assistance of Paul Dolan.

For the data analysis, particularly the discourse analysis presented in Chapter 5, Anne Preston deserves major thanks. Without the assistance of the people mentioned, and many others, this thesis would not exist.

I would also like to thank my examiners, Professor Janet Read and Professor Judy Robertson. I would also like to thank my viva chair, Dr Jonathan Guy.

Collaborations

The work this thesis is based on is part of a collaborative investigation of using digital tabletops in an in the wild classroom setting.

Deployment & Data Collection:

- In Study One (Chapter Four), deployment and data collection tasks involved collaborators Madeline Balaam, Ahmed Kharrufa, Paul Dolan and David Leat as well as myself.
- In Study Two (Chapter 5) deployment and data collection tasks involved collaborators Madeline Balaam, Ahmed Kharrufa, and David Leat as well as myself.

Analysis:

- In Study One (Chapter Four), Ahmed Kharrufa and Madeline Balaam collaborated with me on part of the analysis of Teacher Interview data (resulting in the paper "Tables in the Wild: Lessons Learned from a Large-Scale Multi-Tabletop Deployment" [58])
- In Study Two (Chapter 5) Anne Preston provided a second encoding for the data used in the discursive analysis.

Previous Presentations

Work contained in this thesis has been presented at academic conferences and published in conference proceedings, or abstracts:

Heslop, P., Kharrufa, A., Balaam, M., Leat, D., Dolan, P., and Olivier, P. Learning Extended Writing : Designing for Children's Collaboration. *Proceedings of the 12th International Conference on Interaction Design and Children*, (2013), 36–45.

Kharrufa, A., Balaam, M., Heslop, P., and Leat, D. Tables in the Wild: Lessons Learned from a Large-Scale Multi-Tabletop Deployment. *Proceedings of the 31st international conference on human factors in computing systems, CHI '13*, (2013).

Data collected and analysed during this work has also been utilised in the following publications:

Kharrufa, A., Martinez-maldonado, R., Kay, J., and Olivier, P. Extending Tabletop Application Design to the Classroom. *ACM International Conference on Interactive Tabletops and Surfaces*, (2013).

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Chapter 1

Introduction

The overall aims of the work described in this thesis are to investigate how to design, develop and deploy a Collaborative Learning application for learning tasks not normally considered collaborative, such as Persuasive Extended Writing, and how to expand such an application from a single group to a classroom scenario. This requires overcoming all the challenges that an "in the wild" deployment of this kind might entail.

To address this, the problem is broken down, and the resulting components explored, through examination of the literature and experimental studies. Key components include "What are the benefits of Collaborative Learning?", "How can the concepts of Collaborative Learning be applied to tasks such as Persuasive Extended Writing?", "How can technology be utilised to afford this kind of collaboration?" and "How can this learning task be applied in the classroom?" They are categorised as two main research questions.

1.1 Research Questions

This thesis documents the work towards addressing two main research questions. Firstly, to identify potential benefits of collaborative learning and investigate how those benefits can be leveraged in a learning task not normally considered collaborative, namely the task of learning Extended Writing (in particular the Persuasive genre), by exploiting collaborative learning technology. In summary:

> **Question One:** How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?

This leads to several objectives for the research:

- To identify the benefits of collaborative learning.

- To identify collaborative design elements and technologies utilised in existing work – specifically in the co-located, face-to-face collaborative learning context.
- To investigate a suitable "non-collaborative" task (i.e. writing composition) in order to provide a candidate task for the design.
- To create a mapping for the task to design elements that could be used in collaborative learning (as indicated by previous work)
- To produce and test a candidate design to ascertain if designed-for collaborative behaviours occur.
- To produce guidelines that may be utilised in the general case – i.e. for other "non-collaborative" tasks.

The final two objectives indicate the desired contribution of the work, that is to produce and test a specific design that allows for collaborative learning of a traditionally non-collaborative learning task, and to produce general guidelines for the design of this type of application.

The second question that the work addresses is how such a collaborative learning task can be developed from the single group setting of three or four students to an "in the wild" classroom deployment where all the students in a class engage in the task in multiple groups, or in summary:

Question Two: How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?

This also leads to several research objectives:

- To adapt the collaborative learning design to the reality of the classroom and available technology, producing a realistic candidate application.
- To examine the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment.
- To observe the Collocated Collaborative Writing application(CCW) in action over a number of sessions in order to analyse both the engagement process and the collaborative performance of CCW.

These objectives lead to further contributions, namely how to design a study for similar applications in the classroom (by investigating the engagement process) and to devise a method for evaluating an application in that "in the wild" context.

1.2 Research Plan

In order to fulfil the research objectives outlined above, a program of research activities is required. This research plan shows the planned actions required to complete the work and ultimately formulate the content of this thesis. This is summarised in Figure 1 below.

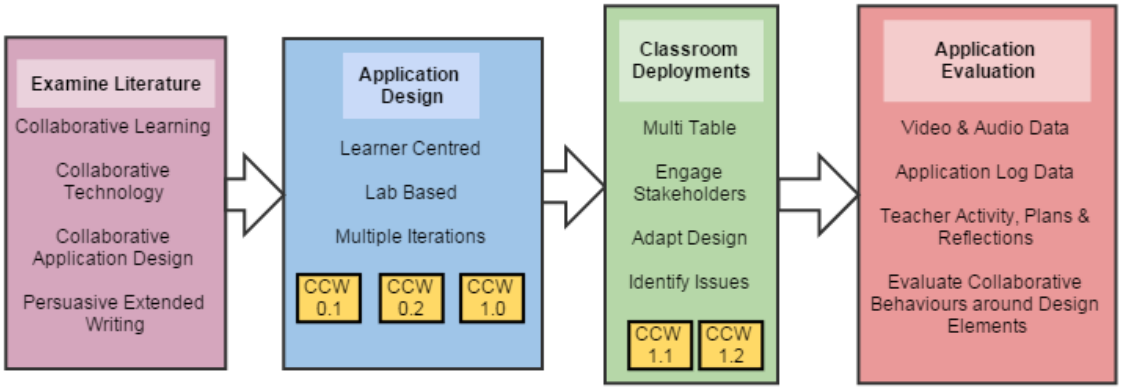


Figure 1: Research Plan (with CCW Versions)

1.2.1 Leveraging Existing Knowledge: Literature Review

The first action is to identify existing research in the literature that can provide answers or partial answers to that meet specific objectives outlined above. To this end, a literature review will target specific objectives focused on identifying existing knowledge and theories:

- Identify the benefits of collaborative learning.
- Identify collaborative design elements and technologies utilised in existing work – specifically in the co-located, face-to-face collaborative learning context.

Section 1.3 below summarises these findings, while Chapter 2 provides a much more detailed investigation. Additionally, an exploration of the literature yields insight that forms the basis of the initial investigation work, i.e.

- Investigate a suitable "non-collaborative" task (i.e. writing composition) in order to provide a candidate for the design.
- Create a mapping for the task to design elements that could be used for collaborative learning.

This is summarised in Section 1.4, and again Chapter 2 provides detail. It also begins to form the basis for the design aspects of the work. The use of existing knowledge is also an ongoing action throughout the research process, and not limited to these objectives only.

1.2.2 A Candidate Solution: Design

Building on the results of the initial literature review, a prototype solution to answer the first research question *"How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?"* is developed, i.e. the objective:

- Produce and test a candidate design to ascertain if designed-for collaborative behaviours occur.

The design process is outlined in detail in Chapter 3, but in summary it uses technology identified from the literature as suitable for face-to-face collaborative learning, that also affords visuospatial interaction. It is also iterative and learner centred, working with users in the target age group (12 – 13) for the learning task (Persuasive Extended Writing). The design process also suggests some general design guidelines that go towards answering the final objective from the first research question:

- Produce guidelines that may be utilised in the general case – i.e. for other "non-collaborative" tasks.

1.2.3 Testing in the wild: Two Classroom Studies

Answering the second research question (*"How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?"*) requires an increase in scale, both in number of participants and in tables, and locating the work in the classroom, i.e. away from the lab. Again, the literature informs this process. Section 1.5 summarises the challenges involved. (Ideally, a single study would provide enough to evaluate CCW; however the reality of the work was that two studies were required). The two studies are presented in chapters 4 and 5 and in the first study, participants were students of mixed ability, year 8 (aged 13-14), studying English, Geography and History, while in the second study, participants were mixed ability year 8 students (aged 13-14) studying English. In terms of research objectives:

- Adapt the collaborative learning design to the reality of the classroom and available technology, producing a realistic candidate application.

Scaling up from a single group and using different technologies requires updates to the design. This occurred in both the studies outlined in chapters 4 and 5. In this sense, the design of CCW is an ongoing process throughout the work.

- Examine the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment.

Taking work out of the lab setting and into the classroom requires domain specific knowledge. It also requires ethical consideration, outlined in Section 1.7. The engagement actions are described in detail at the start of each of the study chapters, and lessons learned from the first study (Chapter 4) are applied in the second (Chapter 5). Getting the engagement right is key to being able to evaluate CCW and allow the final objective to be fulfilled:

- Observe CCW in action over a number of sessions in order to analyse both the engagement process and the collaborative performance of CCW.

Evaluating CCW in terms of collaborative performance is outlined in detail in chapter 5.

1.3 Collaborative Learning and Technology

Dillenbourg provides an intuitive definition of collaboration: “a situation is termed 'collaborative' if peers are more or less at the same level, can perform the same actions, have a common goal and work together” [30] (p7). Activities that have these characteristics, and have the shared goal of learning, can be classified as collaborative learning. This is the basic definition of Collaborative Learning used throughout this thesis.

Collaborative learning is a well-established field. Building on early work by Vygotsky [132], who theorised that learning was a process of externalising and then subsequently internalising thinking, and that collaboration was one way that this process could manifest itself. He developed the theory of the Zone of Proximal Development, whereby a learner’s potential is greater than their current ability, and working with others with differing expertise subjects the learner to activity beyond their current level but within that of the group. This gives a learner opportunities to internalise the externalisation of the group’s thinking rather than just their own. When the group takes advantage of the expertise supplied by a teacher, this process can be magnified, elaborated and deliberately encouraged. This expertise-based assistance from the teacher is known as scaffolding and was developed by Wood et al. [140,141]. Scaffolding is a small-scale intervention designed to help a student with an immediate problem to allow them to continue with the overall task. It can also “fade” as such assistance becomes less necessary.

The thinking processes within a group can be described as Distributed Cognition [89], a way of thinking about dividing large tasks across collaborative users. It is closely linked to the concepts of externalisation and internalisation in collaborative learning. In particular, the idea of utilising a shared space to make representations [67] of thinking lends itself to the small group setting that

commonly occurs in the classroom. Using technology to support Distributed Cognition, particularly in the field of learning, is a vibrant research area [11,28,29,47,64,107,112,143].

Visuospatial representation [67,143], that is where ideas can be represented visually through abstract manipulatable elements, is an embodiment of Distributed Cognition that can be exploited for collocated groups. It allows collaborators to show their thinking, but also change and build upon the thinking of others by altering the presented representation.

There are a variety of technologies leveraged for collaborative learning, from social media [16,56] to virtual environments [142]. For the collocated, face-to-face collaborative setting, digital tabletops provide a promising medium [26,46,60,61,63,83,116]. They are inherently face-to-face, provide a shared space for idea representation and through appropriate design can provide automated scaffolding. They are also ideal for the kind of visuospatial applications that allow for communication of cognition through representation. Digital tabletops are used in a variety of Learning Applications [60,105] that exploit these affordances.

Chapter 2 of this thesis, in particular sections 2.3, 2.4, 2.5 and 2.6 explore the concepts of the collaborative learning, and the technology that aims to exploit it, in detail.

1.4 Designing Collaborative Learning of Persuasive Extended Writing

Extended writing refers to any writing task that requires significant effort, is well structured and is generally a more complex process than simple text generation. It usually includes peripheral activities to the actual generation of text, including idea generation, planning, drafting, revising etc., and can be applied across formal writing (such as scientific writing) as well as creative writing.

Most existing digital tabletop applications are developed from existing collaborative visuospatial tasks [60]. This work aims to apply these principles to learning how to compose Extended Writing (specifically Persuasive Writing), a learning task that is usually taught on an individual basis. If a suitable visuospatial collocated collaborative application can be designed, then it is possible that the

design process can be generalised and therefore able to be utilised to bring the advantages of collaborative learning to tasks usually taught on an individual basis.

Extended Writing composition was chosen as it is a suitably difficult task to learn and is usually taught on an individual basis [43,86]. It is sometimes referred to as Structured or Academic writing, and comprises a formal structure, specialised vocabulary and requires a greater understanding of the purpose and audience of a piece of writing. It also includes peripheral activities to the actual generation of text, such as idea generation, planning, drafting and revising [39,55]. One method of teaching Extended Writing is the Writing Frame [76], which specifies particular genres of common Extended Writing documents. It also provides a framework-like structure which although rigid in the original design, can be adapted into more dynamic representations [15].

Chapter 2 explores the topic of Writing and Extended Writing in detail, in particular in sections 2.1, 2.1.1, 2.1.2 and 2.2. Chapter 3 outlines an initial design process for a Collocated Collaborative Extended Writing Application (for the Persuasive Writing genre) based on the ideas of Collaborative Learning and Distributed Cognition. The process is learner centred – volunteer learners helped to test three iterations of CCW in a lab setting, providing feedback and suggestions, while CCW monitored their interaction alongside video recordings. Chapter 3 also suggests some general design guidelines to take forward for designing applications for learning tasks normally taught on an individual basis.

1.5 The Classroom

Integrating technology into the classroom is a significant challenge. There are many practical considerations, especially when utilising technology, such as digital tabletops, not usually supported by a school's infrastructure. The reliability of the technology can also be an issue, with multiple tables in a time and space constrained environment presenting more technical problems than a single table in a lab. In addition, the deployment needs to be scheduled around a school's existing activities, and there is always the possibility that the schedule necessarily will change as the school's activities change.

Aside from these practical issues, there are major differences between the classroom and the university lab.

- Users of the system are not necessarily enthusiastic volunteers, but rather learners in an ordinary classroom setting – with the normal accompanying behavioural and motivational issues.
- Teachers and not University researchers facilitate sessions. Teachers are the domain experts in the classroom, and may not have been party to the development of the technology (in which case they would need time to learn how to exploit the technology in their practice).
- Curriculum pressures mean that the content of the learning task must closely match the topics that the learners are already engaged with, otherwise there is the danger that the deployment is not seen as beneficial, or even as a waste of time.

Chapter 4 details the planning and deployment in a school of the Collaborative Writing Application. It documents how some of the above challenges arose, and how they were met. Teachers were engaged in the process from an early stage. They were introduced to CCW, and produced the content for the sessions in line with their curriculum requirements. Sessions were recorded on video, both at classroom and table level, and CCW recorded interactions. In addition to the sessions on the tables, the disposition of the students was recorded (using Pupil View Templates [134]) at several intervals during the study. The chapter also details how the design of CCW evolved to respond to these challenges. The chapter concludes with an evaluation of the deployment, recognising that the expectations of the different parties were different, and a greater understanding of these would lead to a more impactful study. These expectations are summarised into a number of key issues to be addressed when undertaking this kind of deployment.

Chapter 5 documents a second classroom study. This deployment took the lessons learned from the previous study, attempting to incorporate the differing expectations into the planning stage – attempting to make clear the limitations of the technology as well as the advantages. The focus of the study was not solely on the learners' appropriation of the technology, but also on that of the teacher. The teacher was encouraged not only to make content for the study, but also to incorporate the technology into her lesson plans. After reflecting on the data capture process in the study outlined in chapter 4, this study follows the progress

of one group across all the sessions. This shows how interactions with CCW and communication within the group develop across the study. Reflecting the more balanced focus of the study, focusing on the teacher as well as the students, the chapter also provides more detailed analysis of the teacher's interactions in the classroom, as well as the teacher's plans and feedback, to get a better picture of how the teacher appropriates the technology into her practice. The focus of the study is not only on CCW's impact on the learners, but on the impact of CCW on the classroom and in particular the teacher's behaviour.

1.6 Discussion

The final chapter in this thesis (Chapter 6) contains a discussion of the findings of the work outlined elsewhere in the thesis. In particular, the chapter is concerned with how far the work met with the research objectives described above.

The main contributions from this work are a set of guidelines for designing a collaborative learning application from a learning task not usually thought of as collaborative, and insights into how such an application can be extended from the single group to the whole classroom. The learning of Persuasive Extended Writing is used as an example of such a task – and lessons learned from the design of the collaborative writing application are generalised. The second contribution comes from lessons learned from the two studies outlined in Chapters 4 and 5. It builds a deeper understanding extending the learning task to the classroom by considering the expectations of the parties involved, understanding the culture of the schools fostering a research partnership with the stakeholders.

The chapter also discusses limitations of the work and points to future research that could build on the findings presented here.

1.7 Ethics

The research was conducted with full ethical approval from the university and the schools involved. To ensure high ethical standards, the university provides an "ethical toolkit", incorporating an ethical application that must be completed by the researchers and then assessed by the University Ethics Committee. Appendix H contains a copy of the ethics form completed for these studies. It is then required

that the participants in the study (i.e. students, teachers and the schools themselves) are given sufficient information to give informed consent.

A short introduction presentation was given to the teachers and other members of staff before each study, to explain the aims of the study and outline the technology involved, what data recording would be used, as well as to explore any concerns that the school may have about the study. The result of these discussions was to use an adaptation of the school's existing processes for gaining parental consent, rather than a complete redesign.

The researchers were then introduced to the students during normal lesson time while teachers were present to introduce the study and field any questions. Students were informed of the process (i.e. gaining parental consent), given details about what would be recorded, how it would be used and they were also given the opportunity to not participate.

The schools involved had their own procedures for obtaining parental consent for the participants – this required the use of the school's parental consent form. These were adapted for the specific requirements of the studies, i.e. a description of the study process and its goals, an explanation of what data would be recorded and how it would be used, and an option to exclude their child from participation. An example is included in Appendix H.

Additionally, participants in the studies were also given an information sheet outlining the scope and intentions of the study, and afterward a "debrief" sheet, thanking them for participation and reminding them again of the study content. Examples of these documents are included in Appendix H.

Chapter 2

Literature Review

In order to begin answering the research questions outlined in the introduction, an understanding of previous work in the areas concerned is required. This chapter examines the relevant literature in order to gain such an understanding. The first question, "*How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?*" initially requires identification of a learning activity that is usually non-collaborative. To this end, the task of learning how to write, or more specifically how to do Extended Writing (in particular in the Persuasive genre), is chosen. The chapter begins by introducing "writing", and in particular the concept of Extended Writing. The chapter then investigates how technology has been used to support collaborative writing, although usually as a non-collocated composition tool rather than a learning one. The chapter then addresses how writing is currently taught, and how current methods differ from those used historically. The concept of writing frames is introduced, a method for teaching Extended Writing (and in particular Persuasive Writing) by using framework-like elements.

This review also needs to address the concept of collaborative learning, specifically what are the benefits that the future application will need to exploit, and how might the design incorporate those benefits. Section 2.3 explores collaborative learning, starting from Vygotsky [132] and incorporating concepts such as scaffolding, Distributed Cognition, and visuospatial representation. The chapter goes on to investigate technology used for collaborative learning, in particular digital tabletops.

The second question, "*How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?*" requires knowledge of the "in the wild" context of the classroom, and what differs from a single group deployment. Section 2.7 provides an overview of the classroom, including the concept of orchestration. Finally, section 2.8 provides a summary.

2.1 Writing

Writing is a way of representing, externalising, communicating and recording information. It is a fundamental skill taught in various forms and complexities from early pre-school through to post-doctoral. Such a wide and varied topic as writing has many sub-categorisations, as the style, language and structure are tailored for a specific purpose and audience; the writing is geared towards a specific communication goal. For instance, "creative" writing can be thought of as an informal style of writing that attempts to convey some kind of narrative, story or other product of the imagination. However, even within this sub-category, structure and language are still prevalent, with "rules" governing the form of particular writing forms such as poetry, or a play and can be thought of as Extended Writing. The nature of creative writing however means that rules are not always strictly adhered to. Writing, and in particular Extended Writing, is one of the most difficult skills to learn [43].

2.1.1 Extended Writing

Extended writing usually includes peripheral activities to the actual generation of text, including idea generation, planning, drafting, and revising. These "extra" activities have received attention from computing science for a number of years. In the 1980s, Ronald Kellogg [55] suggested several "idea processors" – computer programs that could aid in generating and organising ideas for an Extended Writing task. He separates the writing process into four distinct stages - collecting information (reading, listening, and searching bibliographic sources), planning text (creating ideas, organising ideas, and setting goals), translating plans into text (constructing legitimate sentences, i.e. actual language production), and reviewing text (reading, evaluating, editing errors). Idea processors can be made for all these areas, and aid the writer by reducing "attentional overload" (trying to do too many things at once), "idea bankruptcy" (the inability to come up with relevant ideas) and "affective interference" (the anxiety and emotional fears of writers during composition, e.g. procrastination). Kellogg suggests that computer programs can act as a "funnel" to concentrate activity to pertinent actions (i.e. task separation), an "inventor" to generate new ideas and thinking, and a "therapist" to help relieve affective pressures.

2.1.2 Collaborative Writing

Co-authorship of documents occurs in many fields, such as producing research papers, but also in other fields such as writing fiction. The expertise of multiple authors is harnessed to produce a single piece of work that benefits from each party's contribution. In computer science, tools designed to facilitate collaborative writing tend to be geared towards allowing non-collocated collaborators to work on the same document simultaneously, using colour coding and annotation to identify individuals actions [4,37]. Technology has mainly been leveraged to enable co-ordination (enabling actions to be done visibly and simultaneously), with higher-level concepts of collaboration (e.g. communication) left to the human users.

Even in a collocated environment, identification of actions – feedback on what is happening and who is doing it - is useful (at least from a Distributed Cognition viewpoint). Collocation removes many of the communication problems (i.e. without lag, low resolution video, restricted view, lack of gestural interaction etc.), which can be a significant issue with collaborative writing [4]. Collaborative writing in a pedagogical context facilitates socio-cognitive learning by encouraging discourse between users [70].

2.2 Learning Writing

In order to achieve the goal of designing a collaborative writing application for the classroom, an understanding of existing teaching methods for writing is needed. In particular, as CCW will be concerned with Extended Writing (in the Persuasive genre), the focus of this section is on how this type of writing is taught. Richard Ings [51] investigated the state of teaching writing in his "Writing is Primary" report. This work involved a two-year study to develop continuing professional development (CPD) models for developing teacher confidence in the teaching of writing. He indicates that even at primary ages, it is important that teachers are themselves accomplished writers. Young learners pick up easily on teachers' behaviour, in particular, reluctance, as one child commented: "I don't think she minds writing but she'd like to do less of it, I'm sure. We all would" (p5). The report also states that the standard of writing often falls short of the standard of reading

in primary schools, a discrepancy that is often not addressed until secondary school.

Galbraith and Rijlaarsdam [39] provide an introduction to the field, explaining current and historical teaching practices. Teaching methods have changed over the years. Before 1970, learning to write was based around transcribing language into a written form. This included learning spelling and grammatical conventions, learning the principles of a good style by example, and learning conventional text structures – how to write was not articulated. Post 1970 writing has been viewed as a process of problem solving; ideas are actively constructed to satisfy communicative goals.

Newer methods require the use of a variety of cognitive skills, such as planning, translating and reviewing. These tend to be applied in a recursive manner under the guidance of a teacher (or other authority). The key difference in the two approaches is that the latter focuses on goal satisfaction rather than linguistic characteristics (and the processes to achieve those goals). That is, learning to write actually involves learning about the different processes involved in writing, and how to coordinate these in order to satisfy goals that vary depending on context, task and audience. This leads to specific goal-focused writing activities in the classroom (for example: journal writing; peer conferencing; collaboration in small groups; brainstorming; outlining; free writing; multiple drafting; peer revision; writing for different audiences; class publication etc.) These contemporary methods lend themselves to Extended Writing. Ideally, successful writing (and teaching of writing) strikes a balance between the creative expression of the author and the structured approach required to meet specific goals [86].

Even informal writing can have structure – a piece of creative writing such as a story is stronger if certain elements are in place (for example a point of view). Mason [79] provides a teaching guideline that covers these structural elements, and goes on to cover Extended Writing (or as Mason terms it, academic writing) structures as well.

2.2.1 Learning Extended Writing

Writing generally is one of the most difficult skills that learners are expected to master in the classroom, as observed by Graham and Harris [43] : "Writing is a self-initiated, self-directed, and self-sustaining activity of composition and inscription that requires the orchestration of a wide array of cognitive processes". Non-fiction, structured writing tends to be particularly challenging for learners [65] due to specialist vocabulary requirements, the structure of the writing itself and the ways in which parts of the writing are connected.

Galbraith and Rijlaarsdam [39] outline complementary approaches to teaching (extended) writing that focus on three key areas of development:

1. developing the ability to direct writing towards communicative goals;
2. developing the ability to coordinate and manage the different processes which make up writing;
3. Developing an understanding of the social context within which the writing process is embedded and of the social process of writing.

To accomplish these aims, they suggest designing writing tasks that *develop intentional cognition*, that is, focus on the outcome of a writing task so that it fulfils a specific communicative goal. They observe that this is one of the fundamental differences between a novice and expert writer – novice writers tend to use a "knowledge building" (or think-say) strategy [24] that can end up as a listing of facts rather than a well-structured document, i.e. it lacks a point of view. Planning and revision exercises can also fall into this trap if the commutative goal is not considered. Experts on the other hand perform a "knowledge-transforming" exercise [24] when writing. They have an audience in mind, and write from a point of view for that audience. Ideas are not just retrieved directly from memory but are actively constructed and evaluated with respect to communicative goals, and planning and revision are more involved and elaborate, mediated by the writer's goals. To transform novices into experts, learners need to be made aware of the variety of activities involved in writing, including goal setting, common structures and formulations, how to evaluate and plan towards goals. Secondly, they need assistance during the writing process, to incorporate goal-directed thinking, especially with tasks that require knowledge transformation (e.g. persuasive or discursive texts) through external prompts (or scaffolding, see section 2.3.2).

Galbraith and Rijlaarsdam [39] also identify some common obstacles encountered by the novice writer in making the transition to mastery of the task. Novices tend to regard writing as a unitary process, in which planning, translation and revision are carried out simultaneously, while experts view them as distinct activities. Effective writing depends not just on goals but also on ability to coordinate these different processes. Separating the writing task explicitly: e.g. make an outline first, and then design a structure etc. can be effective, as can activities like brainstorming and journal keeping that focus on generating ideas freeing up the writing task for structure and intent. Dividing the task up can also help with cognitive overload, that is treating the task as a unitary one meaning it is too large to think about effectively [38].

The social nature of writing is also discussed by Galbraith and Rijlaarsdam [39]. They point out that the goals writers should strive for are not individualistic (or there would be no audience) but are social in nature, they reflect the cultural, personal and academic background of the writer. It can be challenging writing for an unfamiliar audience, as the conventions of the audience can be different from the writer's experience. This can become an issue for teaching as well, as there can be contrasting assumptions made by the students and their teachers about the purpose of a piece of writing. The teacher's assumptions can often be tacit and unexplained, leaving the learner confused. To remedy this, learners should be made familiar with the underlying functions of different writing conventions.

From a social point of view, the source of the conflict is not so much cognitive overload as a lack of experience as there is a conflict between the writer's private, unarticulated conception of a topic and the constraints of articulating this within a particular set of public conventions.

De La Paz and Graham [72] also provide an overview of some of the strategies, skills and knowledge required to perform well at the writing task, all of which can be applied to Extended Writing. They focus on school age children (7th and 8th grade, 12-14 years old). They observe that a major part of successful writing is planning, a process that is often minimised by school-age learners – who approach writing iteratively, i.e. by retrieving topic related information from memory, writing it down, then using this to stimulate subsequent recalls in order to generate the next sentence [113]. Little attention is given to the needs of the

reader, or to constraints imposed by the topic, or even the organisation of the text – areas that can be focused on in the planning stage. Skilled writers plan not only what they will write but also how they will write it. They establish goals, structure their ideas, and consider their audience. A written plan provides an externalisation of memory. The writer stores ideas without the risk of losing them, and it reduces the need to plan during the composition process. This allows the writer to use their resources to engage in other writing processes, such as translating ideas into words, transcribing words into printed text, or reviewing and revising text [55].

De La Paz and Graham [72] conducted a study involving advanced planning techniques with learners. They used the procedures developed by Whitaker et al. [137] and further developed by Berniger et al. [9] to assess the quality of the plans - all written plans received a score for level of development, scored on a 5-point scale. Final essays were assessed for vocabulary, length etc. by two independent teachers. They found a strong correlation between good planning and high quality writing.

Kirkpatrick and Klein [65] also conducted a study to see the impact of planning on Extended Writing – explicitly in the compare-contrast genre of writing. The planning task was based around a pre-made structure in the form of a table where learners filled in specific columns related to their writing plan. The columns were labelled: Information [first topic], Information [second topic], Aspect, Paragraph, and Number (IAPN). The information headings are for the learners to select information from a source text, the Aspect column allowed learners to organise and connect information into aspect- based comparisons, the Paragraph column allowed grouping of information into paragraph like structures and Number allowed learners to order the paragraphs. The study involved having a group use the IAPN table to help them plan and structure a document. Their work was compared with a control group. The study found a large positive effect from their intervention when compared with the control group, particularly in low performing students (statistically significant writing grade gain of 2.00 (0.09 for control) from pre-test grade to post-test grade).

Coffin et al. [20] pg 34, provides guidelines for teaching the writing process by dividing it into several stages, as illustrated in the diagram below (Figure 2).

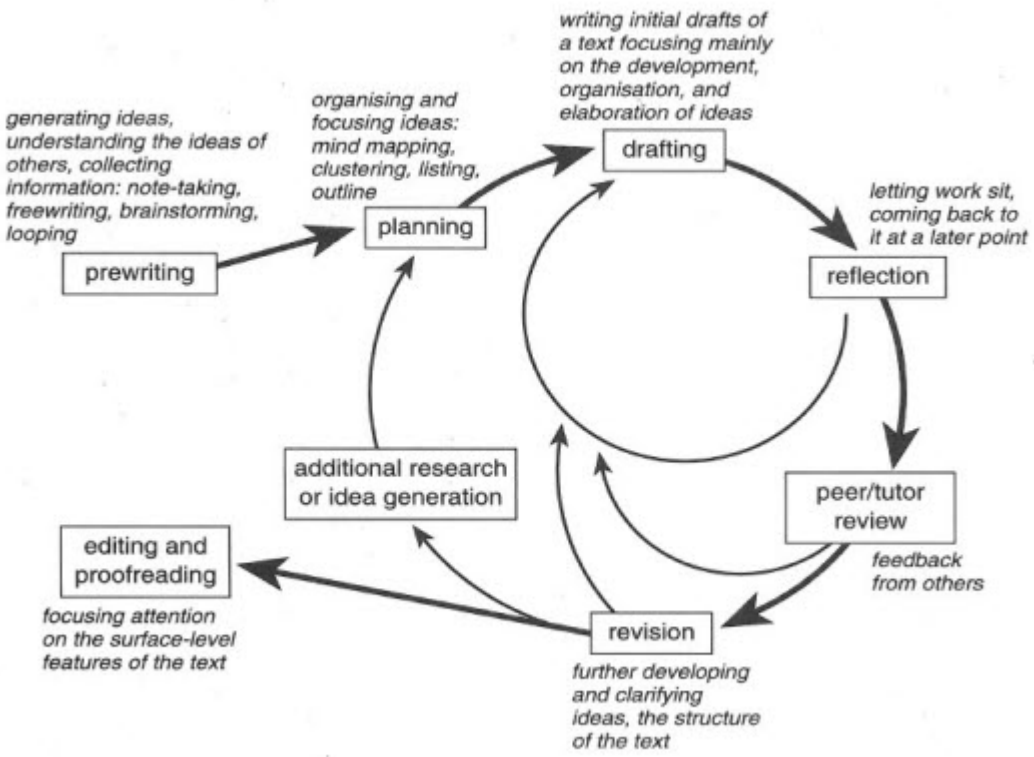


Figure 2: Coffin et al. Writing Process

As the diagram (Figure 2) illustrates, the writing process is not linear, and different stages can be revisited. Of particular interest is the *planning* stage, as this stage in the process maps the results of the pre-writing investigation into a specific structure with a definite communitive goal. This structure can be quite different to how the prewriting results are organised, and is as such a re-representation of ideas to fit a specific communication goal.

2.2.2 Writing Frames

One method for teaching Extended Writing is "Writing Frames" [76]. Writing Frames are template-like scaffolding constructs that provide the framework for structured documents, i.e. starters, connectives and sentence modifiers. There are various genres available, so students experience a wide range of generic document structures. In particular the persuasive writing genre provides a document type that can be difficult for learners as it requires the creation of a persuasive argument across several paragraphs, including supporting evidence and consideration of (and counterarguments to) alternative interpretations. The templates provide cohesive links to help children maintain sense of what they are

writing and include a varied vocabulary of connectives, sentence beginnings etc. which students may not be initially familiar with. To complete a writing frames task, the student needs to select and think about the order and structure of the information in the document and demonstrate understanding of the process. It should begin with a teacher demonstration, then a joint activity involving the teacher and the students (i.e. a high level of scaffolding), followed by a student-only scaffolded writing task using the writing frames templates (i.e. a lower level of scaffolding) and finally an independent writing activity. The students therefore begin learning in collaboration with an expert and work through to being independent learners and finally experts themselves.

The effectiveness of Writing Frames depends largely on how they are incorporated into the classroom. As reported by Warwick et al [135], in order to be effective, the teacher should:

- have a clear understanding of the objectives of the session;
- share both the learning objectives and the assessment criteria for the session with the pupils;
- be clear, in the structure of any writing frame, about which concepts of evidence are to be focused upon;
- understand his/her role in scaffolding the pupils' experience through the use of the writing frame; and
- understand the central importance of social interaction to learning, and therefore to encourage pupil–pupil and pupil–teacher collaboration.

The paper based exercise is somewhat limited in the fading of scaffolding, and the pre-determined frames are not flexible [15] and are designed for individual use. Bruce [15] expands on writing frames by pointing out some potential pitfalls, and introducing a dynamic element. He points out that Writing Frames in its standard format can be too rigid. Pitfalls with Writing Frames include:

- It can focus learners on set answers
- Is restricted to a few pre-set frameworks
- Can put off learners who have "visual or other preferred learning styles" – though the concept of learning styles is contested.

- Can lead to similar pieces of work across the group
- Following the structure can become the focus, rather than content
- Learners select information to fit the framework rather than answer the question

Bruce suggests a dynamic version of writing frames where structure and content can be treated separately and rearranged using magnetic stickers on a whiteboard.

2.2.3 Learning Writing Collaboratively Using Computers

In section 2.3, the topic of collaborative learning and its benefits is covered in detail, and section 2.4 covers the topic of designing technology specifically for collaborative learning. However, there have been studies in the field of learning writing collaboratively using existing writing software on standard desktop computers [70,71].

In particular, Kumpulainen [71] conducted a study with children (aged 11-12, based in UK and Finland) sharing a single desktop computer interface using a standard word processing package. The requirement of learners to share the interface in such a manner naturally increases the need for dialogue and negotiation. Kumpulainen argues that collaborative learning through discourse is the means through which interpersonal meanings are established. Learners construct their knowledge and express their opinions, values and feelings to each other. The process also allows the teacher to step back and take the role of a facilitator of children's learning. The learners are able to take more control over their working and increase their responsibilities. (This change in role of the teacher to being a facilitator or a provider of expertise is discussed in section 2.3.2 and the social and cultural aspects of learning are discussed throughout section 2.3).

The work analysed the discourse of learners in the context of their actions within the writing task. (However, as Kumpulainen points out, every method of analysis aimed at investigating such rich data as classroom interaction has evidently its own limitations i.e. it is not possible to capture everything.) As writing (or speaking) is both a process and product designed to be a social exchange of meanings - the two processes can inform each other. The analysis noted the tone

of discourse, revealing information about the participants (e.g. roles, statuses, social relationships). The mode of discourse reveals information about the role of language during interaction (i.e. what functions does language serve in a particular context? Is it spoken, written or both? What achievements are made by the use of language and particular functions? What status is given to the language?). The work used a functional analysis methodology to identify sixteen individual functions of talking or writing: Intentional, Responsive, Reproduction, Interrogative, Experiential, Informative, Judgemental, Hypothetical, Argumentation, Affective, Compositional, Organisational, Expositional, External thinking, Imaginative and Heuristic.

The work therefore identified some of the purposes of collaborative discourse, but concluded "data suggests that the reasons for the findings are not associated with use of computers alone. Instead, ways in which children interact and write while using computers are embedded in wider socio-cultural contexts of which children are a part". In other words, writing is facilitated by technology but is generated by a socio-cultural requirement for communication.

2.3 Collaborative Learning

Learning collaboratively can have advantages that individual learning does not, and has been shown to be beneficial in several areas, such as collaborative search [18]. For certain tasks, group work leads to better problem-solving and learning outcomes [7]. Collaboration is built upon communication, which should be afforded by any technology designed to allow collaboration. In particular, working in the same location face-to-face (collocated collaboration) maximises the communication space between collaborators. In distributed collaboration, communication is restricted, even if technology such as video conferencing can alleviate this to some degree [10].

It is important to establish what is meant by collaboration, as the term has different connotations depending on context, scope and goals, as highlighted by Dillenbourg [30]. Dillenbourg identifies the fact that collaboration has many different definitions depending on context, varying in Scale (number of participants), Task and Togetherness (collocated vs. distributed, simultaneous vs. turn taking, over what timescale). He goes on to provide a basic intuitive definition

of collaboration: “a situation is termed 'collaborative' if peers are more or less at the same level, can perform the same actions, have a common goal and work together” [30] (p7). Activities that have these characteristics, and have the shared goal of learning, can be classified as collaborative learning. Dillenbourg expands on this by identifying collaboration as a social contract between the peers or between the peers and the teacher (then it is a didactic contract). This contract specifies conditions under which some types of interactions may occur, but does not ensure that they do.

Kirshner et al. [66] describe the effectiveness and efficiency of collaborative learning - collaborative learning is considered effective if learning goals are obtained and collaborative learning is considered efficient if learning goals are obtained with the investment of less mental effort. The more complex they made the task in the study (i.e. the higher the intrinsic cognitive load), the more effective it was for learners to collaborate.

2.3.1 Externalisation, Internalisation and Collaboration

Vygotsky [132] suggested that the process of learning involves the internalisation of previously externalised cognitive processes. This process is linked to communication - learners first learn from another through communication (i.e. socially), then through “thinking out loud” (i.e. the learner has externalised part of the cognitive process), then finally through the internalisation of the “out loud” process. The act of writing itself is an example of this process [26], both as a way of expanding short term memory but more importantly a way of changing our thought processes in order to understand abstract concepts. It is also an act of externalisation and extending working memory [32]. The simple example of a shopping list illustrates this, but it is also a method for an individual to clarify their thinking, and of course to communicate thinking to others.

Vygotsky also introduced a model of learning based around a measurement of a student’s current “potential” – the level a novice can achieve with “expert” support - being greater than their current individual ability. This is known as the “Zone of Proximal Development” (ZPD), and it is the closing of this gap (by providing progressively less assistance) that learning takes place.

Piaget, while taking a different approach to the idea of learning than Vygotsky, also saw benefits in collaboration - collaborative activity exposes learners to different viewpoints (and possible solutions), helping develop critical thinking skills and more complex understanding [92].

2.3.2 Scaffolding and Fading

Wood et al. [140] described the expertise-based assistance provided during the collaborative learning process as "scaffolding", and the process of gradually removing the assistance as the student improves as "fading". Wood outlined several principles that define scaffolding and, in a later paper, Wood et al. [141] expanded upon these principles to describe what kind of expert assistance is appropriate for a student. Experts give proportional support, which is reduced as the student becomes more able (fading).

Reiser [100] explicitly discusses the use of scaffolding within learning applications. He argues that successful scaffolding has two functions, firstly software tools can help structure the learning task and secondly they can shape students' performance. Guiding learners through key phases, such as supporting their planning, can accomplish the first function. For the second function, tools can aid understanding of the task in terms of requirements and mandatory processes that the task demands, which are not necessarily obvious to a novice learner, e.g. specialised content and strategies. Learning these processes can be thought of as reaching sub-goals that lead to overall good performance in the main task.

Diaute and Dalton [25] investigate further into the role of "expertise" in scaffolding, with particular regard to literacy. They conduct a study with fourteen children aged seven to nine, working both individually and in pairs on a standard word processor over a three month period. They point out that at different stages in a task, different expertise within the pair can lead to learners providing expertise-like scaffolding for their partner. In their work, they observe that collaboration among "novice" peers is similar in nature to that between experts and novices in some respects, in particular the transfer of ideas and solutions. Communicating thoughts also allows them to be externalised and then examined by others, i.e. their partner. In some cases, explaining (as a learner) is as important as being explained to. They conclude that, provided the skills required to complete

a task are represented across the group (or partnership) as a whole, that novice peers are almost as effective as experts – assuming the group (or pair) work cooperatively.

Scaffolding need not take a single form throughout a task (for example teacher intervention). Tabak [128,129] describes the concept of Distributed Scaffolding – where scaffolding takes multiple forms to address different learning needs or across distributed settings. He describes how scaffolding can take different forms, but should be linked, depending on the current activity across a curriculum (e.g. reading science – individual text book work, doing science – conducting experiments in groups, discussing science – classroom discussion etc.)

There are significant aspects of scaffolding that are hard or impossible for software to implement (such as capturing the communication aspects of collocated collaborative tasks, both vocal and gestural for example) [141], the purpose of the software should not be to replace the interaction of a teacher but to work alongside the teacher.

2.3.3 Distributed Cognition

Many problems lie beyond the scope of the individual, and systems need to be designed to cope with the scale, complexity and disparate nature of these problems [3]. One method, closely linked to the concepts of externalisation, collaboration and the use of shared space, is the concept of Distributed Cognition [47,89,107]. Distributed Cognition is a way of thinking about dividing large tasks, particularly across multiple collaborative users and across the environment or tools that are used to represent and interact with the task. Users of the system are working towards the same goal, and need to be able to act individually whilst ensuring that all users are aware of one another's actions. In other words, all users should be aware of the current state of the task, as well as aware of others' actions and the resulting effect on the state. Individuals' actions should have clear consequences that change the state of the task, such that all users are aware of the resulting task state. Actions should also be non-permanent, allowing collaborators to change or remove each other's actions. It is also useful if collaborators can externalise their internal representations of a problem, for example by visually representing it through some shared collaborative space (for example by using props or a

diagram). In doing this, collaborators are not only reducing their own cognitive load and re-examining the data through a different representation, but they are also allowing their collaborators access to their thinking process. Zhang and Patel [143] provide a useful definition, by considering Distributed Cognition as "a cognitive system whose structures and processes are distributed between internal and external representations, across a group of individuals, and across space and time" (p340).

Communication between collaborators is vital, as Boland et al. [11] state: "A Distributed Cognition system supports interpretation, and dialogue among a set of inquirers by providing richer forms of self-reflection and communication".

There are various reasons for considering a Distributed Cognition design approach, for example many problems are simply too large to be considered by an individual, and effective solutions that have collaborative approaches encourage collaborators to buy-in to the solution. At an organisational level, the advent of greater connectivity between co-workers and computer systems has led to many Distributed Cognition concepts being adopted [47], and it is a growing research area in HCI generally. Arias et al. [3] point out that many problems require more knowledge than any single person possesses because the knowledge relevant to a problem is usually distributed among stakeholders. They point out the importance of utilising externalisations to extend collaborators' cognitive abilities and the need to contextualise information to avoid information overload and to increase opportunities for learning.

Salomon [112] and Dillenbourg [28,29] make the link between Distributed Cognition and learning, where the group is considered as a cognitive system and argue that "individual cognitive systems" do not learn in isolation, but by performing activities (e.g. reading, building, predicting) in a social context which trigger learning mechanisms (induction, deduction, compilation etc.) both internally and in others. In the context of a learning activity, this externalisation of a collaborators cognitive process ties in with the Vygotskian idea of externalisation/internalisation as a process to manage cognitive load [108]. A collaborator can externalise thoughts phonologically (i.e. talk aloud) and visuospatially (provided there is a mechanism to support this) in order to aid (or augment) working memory, and internalise later.

Kim and Reeves [64] presented work on considerations required when designing tools for learning when using a Distributed Cognition approach. The work points out when considering utilising a Distributed Cognition approach to design a learning tool, the primary concern remains learning the task, not just the tool. They suggest considering the learner, tool, and activity form a joint learning system. The work also makes the distinction between types of distribution as suggested by Salamon [112] (p333) – Social (where teamwork dynamics and group decision making are key), Symbolic (the use of signs, language and affordances to define meaning), and Physical or Material (the use of visible and tangible elements to augment the task). Most cognitive activities involve some or all of these different distributions. This manifests itself in learning tools as:

1. Cognition is distributed between learner(s) and a cognitive tool (Social);

2. The way in which cognition is distributed is first determined by the intentions of tool designers, i.e., tool affordances (Symbolic).

3. It can then be affected by how the learners decide to use it in specific situations. (Physical / Material).

Kim and Reeves also discuss expertise and its relationship to tool use. They surmise that expertise can be classified as "general" – high level skills that can be applied to any task, "generic" – a high level understanding of the task domain, and "specific" – low level, highly detailed understanding of the task domain. These can then be measured for an individual for a specific task, e.g. through knowledge, functions and representations. Through the learning process, learners gain expertise, their knowledge structure and problem-solving strategies improve (and their use of the tools changes). To some extent, expertise is defined through how tools and aids are used by an individual. A successful cognitive tool should provide enough support for novices to complete a task, while not becoming an impediment as expertise increases.

2.3.4 Visuospatial Representation

In supporting collaboration, it can be beneficial for learners to be able to communicate their knowledge and understanding visuospatially. The benefits of using shared visuospatial representations include reduced cognitive load through

externalisation, a deeper understanding of the problem through re-representation and a means of distributing thoughts and ideas between collaborators [67,89].

Kirsh [67] investigates the use of space as a way of organising cognition and communicating meaning, and that in tasks such as planning, spatial arrangement of information is as important as temporal arrangement. Certain spatial representations have common meaning, i.e. the meaning is readily understood by other collaborators. Kirsh classifies the use of space in three categories:

- Arrangements that simplify choice allow a user to compare and contrast similar bits of information to ascertain which would be the most appropriate in a particular situation;
- Arrangements that simplify perception allow a user to re-represent information in different ways to understand the information better.
- Spatial Dynamics that simplify cognition, which is dynamic manipulation of representations to enable high-level concepts like grouping and connecting of information.

Shipman et al. [120] identifies several primitive visuospatial structures that have a commonly understood meaning, including lists (non-overlapping, linear arrangements of objects of the same type), stacks (overlapping piles of objects of the same type), composites (non-overlapping arrangements of different objects) and heaps (overlapping piles of different objects). They noted that such arrangements signify relationships, and that overlapping signifies that the individual content of objects is significant in the relationship and should not be obscured. The work also observes that large-scale representations are usually composed from some or all of these primitive types.

Rouet [108] summarises the use of visuospatial representations as a means to manage cognitive load by proposing a framework for designing visuospatial applications based around consideration of three main dimensions: individual, task and environment.

Nakakoji et al. [88] developed a collaborative writing system called ART which incorporated a shared visuospatial, manipulatable representation of a document as a collection of paragraphs. ART allowed decomposition of a document as paragraphs, and the interaction ART supported scaffolded dialogue between

designers about the content and structure of a document, for example, allowing users to ask:

- "What parts are missing?"
- "How confident am I that this part fits?"
- "How does this new part complement the rest?"
- "How does this new part affect my view of the other parts?"
- "Is the overall design proceeding according to my intuition and intention?"

Although the motivation for the work differs (the application was designed as a collaborative tool for expert writers rather than an application for learning structured writing), their work provides insight into how a document could be thought of in a visuospatial context by identifying structural components that can be used as visual metaphors (i.e. paragraphs). They do not however indicate the benefits of this in a collaborative setting.

2.3.5 Characteristics of Collaboration

Collaborative working, including learning, is largely a communicative act. Tang [130] conducted a study on collocated adults collaborating on a paper based drawing exercise and identified some of the main characteristics. Collaborators do not just verbalise, they use hand gestures to communicate significant information. The process of collaboratively composing conveys much information not contained in the final result and the collaborative space is an important resource for the group in mediating their collaboration. Activity within the space is mixed and fluent; and the spatial orientation among the collaborators and the space has a role in structuring their activity.

There are certain observable characteristics that are evident in collaborative learning, such as role taking and power relationships. Gelpi Lomangino [40] investigated the nature of collaboration during a collaborative story composition exercise with young learners. Participants worked in pairs writing a story together on a computer, sharing the standard keyboard and mouse interface. The study was conducted over five months, and revealed a wide range of observed interaction patterns. Across the groups observed, there were significant differences in interaction patterns involving varying emphasis on fairness, amount

of control, exploration, and social cohesion. As well as the tasks inherent "create a story" goal, social goals guided learners' actions, such as appearing competent to peers, dominating peers, and creating solidarity with peers. Differential status within partnerships was apparent in the different types of social behaviours. Some behaviours were common across most groups; using peers as resources, expressing opposition, directing a peer instead of instructing, and the use of self-monitoring and repetition. This embedding of collaborative behaviour in the learners' existing social identity is also observed by Dyson [35], who emphasises that the process of learning to write in contemporary early elementary classrooms is a social activity, and this is fundamentally tied to children's own social identity and participation in their peer social world.

Gelpi Lomangino's findings also show that learners collaborated more effectively when negotiating a system for interacting with the tool. That is they agreed upon a system for turn-taking and who would control the tool at any particular time. The work also points out that establishing an environment where learners are encouraged to request information (and acknowledge others' requests) can be critical in supporting peer learning.

2.3.6 Assessing Collaboration

Assessing collaborative behaviour can be more challenging than individual assessment. There are many more factors to consider, like contribution, communication, role taking etc. For learning activities, there is also the possibility that groups can perform well in tasks but individuals do not. This can be because individuals are left out or dominated by other group members. Another possibility is that the groups combined expertise is good, but individuals' expertise only covers part of the task, and they do not develop skills covered by their group-mates. To understand what is happening in the collaborative learning process, it is useful to have robust analysis techniques that scrutinise the process of collaboration and learning, and individual assessment separate from the group activity.

One approach is examining the communicative behaviours amongst collaborators. Communication is a key activity, as it is how ideas and thinking are shared with the group. Mercer [81] described this phenomenon as "inter-thinking",

that is when collaborators share thinking through communication. Mercer [82] also provides a methodology for analysing communication during collaborative activities in the classroom. He classifies children's communication into three archetypical forms: Disputational, Cumulative and Exploratory:

- Disputational talk is characterised by disagreement and more individualised decision-making. Peers make little attempt to pool resources, to offer constructive criticism or make suggestions. It has some characteristic features, such as short exchanges consisting of assertions and challenges or counter assertions ('Yes, it is.' 'No, it's not!').
- Cumulative talk, where speakers build positively but uncritically on the utterances of others. Peers accumulate 'common knowledge' through communication. Cumulative discourse is characterised by repetitions, confirmations and elaborations.
- Exploratory talk occurs when peers engage critically but constructively with each other's ideas. Suggestions are offered for group consideration and these may be challenged and counter-challenged. Unlike during disputational talk, challenges are justified and alternative hypotheses are offered. Peers actively participate and opinions are sought and considered before decisions are jointly made. Compared with the other two types, in exploratory talk knowledge becomes more publicly accountable and reasoning is more evident in the talk.

Mercer also warns against the use of the categories to over-quantify analysis, as simple tallies would lose context and detail from communication events – "such a move into abstracted data could not maintain the crucial involvement with the contextualised, dynamic nature of talk which is at the heart of our sociocultural discourse analysis" [82] (p146).

The correlation between communicative behaviours and overall task performance of groups is examined in more detail by Barron [7]. This study identifies which behaviours are exhibited by high performing groups (and which are exhibited by low performing groups). The major difference is how groups handle proposals (communicative behaviours that suggest a course of action or partial solution to a task). High performing groups accept "correct" proposals (i.e.

those that lead to progress within the task) and reject incorrect proposals, while low performing groups dispute correct proposals more often. The work goes on to suggest analysis techniques that will identify these behaviours.

Price and Jewitt [94] consider a multimodal method for analysing group behaviour. That is, they include interaction with the task "interface" (in this case manipulation of tangible objects) alongside communicative behaviours. In a sense, they are acknowledging that manipulation of the interface *is* a communicative behaviour – peers can observe changes made, the interface can be used to express ideas and cause discussion. In essence, the interface can be seen as a means to *create proposals* along the lines of those suggested by Barron [7]. In addition, this use of an interface to make representations that communicate thinking and the state of the task is closely related to the ideas considered by Distributed Cognition.

2.4 Technology for Collaborative Learning

The development of technology to support collaborative learning has been a significant concern in both education research and human-computer interaction (HCI). The range and context of collaborative learning activities addressed to date is wide, and includes social media [16,56], virtual worlds [142], learning with a virtual peer [19,111] and specific classroom and group level interventions involving mobile computing [21], or even bespoke technology [2,5,19,48,124]. Much work has focused on interaction, or the interface between collaborators and the computer. This ranges from bespoke tangible objects (such as Tangisoft [125] and Webkit [124]), to specific interaction designs that exploit affordances of particular interfaces (such as Attribute Gates [126]). Of particular interest to this work are technological media that specifically afford collaboration, and are somewhat available in actual classrooms.

Interactive whiteboards have become commonplace in many classrooms [109], and although primarily utilised as a tool for teachers, the technology has been appropriated for student collaboration and in combination with other electronic resources such as digital cameras, microscopes, and so on. The work by Kershner et al. [57] and Mercer et al. [80] investigate the use of interactive whiteboards in this collaborative context. Both works are based on a study with twelve teachers of Year 4 and 5 (8 - 10) to evaluate how they could use an

interactive whiteboard in their lessons. The work highlights the range of collaborative activities that interactive whiteboards can support, such as computer-supported, multimedia classroom learning in science and other curriculum areas. As with any technology, the mere introduction of the interactive white boards does not of itself have a transformative effect on classroom teaching and learning. In fact, it may reinforce familiar patterns of teacher-pupil interaction in whole-class teaching. Also, as there is a single whiteboard per classroom, the participants are limited to a subset of students from each class in each session.

The work also suggests methods for analysing collaborative behaviour, In particular the analysis of children's collaborative classroom talk and learning presented by Mercer et al (and building on the earlier work from Mercer [81,82]) is pertinent to other forms of collaborative learning technology, such as Digital Tabletops.

In summary, "interactive white boards can be used collaboratively in a variety of science activities closely related to familiar classroom practice and the children can engage effectively in the collective learning experience that we (the authors) have called the "shared dynamic dialogic space." (Kersher et al. [57])

2.4.1 Collaborative Learning Applications

There have been many applications designed to exploit the benefits of collaborative learning, utilising some of the technologies outlined above. This section highlights work that is pertinent to the design of a collocated, collaborative learning application for writing, that is it is concerned with writing or literacy in general and exploits the type of visuospatial interactions highlighted above.

Telltale is a bespoke technology designed to help young children practice certain oral language skills [2]. These skills are critical for acquiring written literacy. The work is based on a theory of "emergent literacy"; that oral literacy and written literacy are intrinsically linked, or, as defined by Whitehurst and Lonigan [138] (p848), "the (oral) skills, knowledge and attitudes that are presumed to be developmental precursors to reading and writing and the environments that support those developments." Since oral literacy is naturally social, emergent literacy acquisition can be seen as a cognitive and social phenomenon. Sulzby

[127] further defines the phenomenon by observing that developing children "speak written language" and "write oral language".

The *Telltale* toy is a bespoke technology and takes the form of a segmented caterpillar where each segment can have up to 20 seconds of audio recorded. The segments can be arranged in any order (except head and tail) – the structure of narrative can be changed and segments can be re-recorded by children. Segments can also be used simultaneously; the children can separate the task and use each individually. This has advantages over the fixed recording and sequencing that a normal tape recorder would offer.

The study involved 22 children between the ages of 6 and 7, separated into groups by ability level. During the study, children use social rules to keep flow of narrative. For example, if a child includes a particular segment, then their peer builds on that segment rather than dismiss it. The children also learn to use conjunctions between sections, such as "however", "therefore", "and", etc. Although not directly compared with other methods, the study did show disparity between high performing students and low performing students (in the number of conjunctions, number of changes of location or character) and the narrative construction was highly linked to social interactions – for example domination, turn taking etc.

Stringer et al [124] developed *Webkit*, an application that uses both a large graphical user interface and a tangible user interface to teach leaners rhetorical skills. The skills taught have a strong correlation with writing genres discussed in Section 2.2.2, in particular *persuasive* writing. The rhetorical process is concerned with three main areas: Discovery of Arguments (i.e. research) - which concerns the accumulation of *evidence*, a key element of persuasive writing; Arrangement of Material – or how an overall argument can be constructed; and Style, or how the argument can be presented in a persuasive way. *Webkit* focuses on the construction of arguments rather than writing per se, and as such performs a similar role as Digital Mysteries (see Section 2.6). The application uses various media across three phases, each one designed to accomplish one of the areas outlined above. The Discovery of Arguments phase uses printouts of articles to generate a series of statements. These statements are augmented with RFID technology, and children place them onto a pre-made layout to form the "positive"

aspect of an argument, then again for the "negative" and finally for a balanced "thesis". An overview screen shows feedback on how well each part of the argument is covered. The final style phase is aimed more at speaking than writing, with learners asked to talk about their argument assisted by a graphical representation that they can "walk through" using another RFID tag.

The system was evaluated with two groups of 6-8 eleven year old learners over three 1 hour sessions per group.. The evaluation identified areas for improvement in the application (such as using more screens etc.) and focused on interaction issues (such as graphical user interface conventions such as touch screens.) The work concludes that future work could explore a paperless system (provided legibility could be maintained), and that collaborative interfaces allowed more participation from leaners, particularly from those usually considered less articulate. However, the system uses rigid structures, not allowing learners to make their own visuospatial representations and therefore possibly limiting collaboration.

2.5 Digital Tabletops

Digital Tabletop technology is an established research area in the field of HCI, and in Education. Major manufacturers such as SMART and Microsoft have table-based hardware used in educational settings. Wellner's early work in the field [136] proposed that the digitisation of otherwise physical tasks on his Desk would bring the advantages of the digital (easy logging, transfer of data, playback, tracking of data etc.) to the physical environment of his work desk. Although the *DigitalDesk* supported remote collaboration by the connection of two systems, its focus was on the single user. However, this work was the starting point for digital tabletops research, which has largely evolved into investigating multi-user collocated interaction.

Digital tables have been shown to have a positive effect on learning [60,104]. Schnieder et al. [114] discovered that a digital tabletop application can be more engaging than the equivalent pen and paper based exercise. However it is not a given that a tabletop interface is inherently superior for learning [33], and the design of the software must take advantage of the affordances of digital tabletops [63].

Digital tabletops are used in many collaborative contexts, including collaborative learning. Scott et al [116] provide general guidelines for designing a collocated collaborative task for digital tabletops:

1. Allow natural interpersonal interaction, i.e. allow face-to-face communication.
2. Transitions between activities (e.g. subtasks) should not require significant cognitive overhead.
3. Transitions between personal and group work (i.e. between combined and parallel activities) should also be as smooth as possible.
4. If external work is required to complete the task (i.e. outside the application) transitions between tabletop collaboration and external work should have minimal cognitive and physical overhead.
5. Support the use of physical objects.
6. Physical and digital objects should have shared access (i.e. no enforced roles through the interface, e.g. a scribe would have sole control of a keyboard).
7. Support flexible user arrangements, e.g. their orientation around the table.
8. Support simultaneous user interactions.

Digital tables have become widely used as a medium for collaborative learning. Dillenbourg and Evans [26] provide a review of several learning tabletop applications, and suggest four high-level principles for exploiting tabletops for learning:

1. Co-Location – Tabletops are designed for users to work together in the same place.
2. Tables are a social space – what happens on the table should be available to and observable by all users.
3. Tables are for hands on activities – they are well suited to visuospatial tasks and manipulation.

4. Tables afford multi-modal communication – users can communicate by talking, through gesture, through posture and through actions on the tabletop, providing a rich discourse environment.

They summarise their classification of the tabletop space (as opposed to other environments) as "Desk(top)s are personal, table(top)s are social, and (digital) whiteboards are public". The work also identifies potential pitfalls when designing applications for relatively new technologies such as digital tabletops. The first is that the expectations of the technology can be unrealistic, from developers and learners alike. They also warn against over-generalisation of the medium – that is that digital tables are good for certain learning tasks, but not all learning tasks.

Higgins et al. [46] also provide a similar overview of the use of Digital Tabletops in the field of collaborative learning. They aim to identify more precisely the design considerations to maximise the advantages of digital tabletops as a collaborative learning tool. Before considering developing an application, an understanding of some of the physical and physiological constraints of the hardware is needed. The physical size of a shared surface (so that users can use the space effectively) is a consideration. The surface needs to be large enough to display meaningfully the contents of an application, but also for a surface to be shared, and all users should be able to reach all areas of the surface (otherwise the surface can become a discreet set of private spaces) [110,131]. Scott et al. [117] identified that territoriality of the surface still occurs, that is that space next to a user is "owned" by them, but a large surface size can enforce this. The territoriality of a surface is also task dependant – a task design that allows primarily parallel activity without the need to pool digital resources with collaborators naturally lends itself to more territorial behaviour. This territoriality negates some of the advantages of the shared social space, as users are less aware of each other's actions and thinking. Although group size (i.e. the number of participants) may be important for a task [54], Ryall et al. [110] found that it is not a function of the table itself (beyond physical restrictions). The design of the interface can have an effect of group dynamics [84], with "private" areas of the interface leading to territoriality. This can be a problem when there is a limited resource in the

interface that group members wish to use simultaneously, (e.g. a toolbar), but having a tangible object that enforces turn taking can help resolve potential conflicts [91].

Kruger et al. [69] studied the impact of orientation on tabletop interaction. They found that simply reorienting content to a user's view while important for comprehension is not the only factor. People use orientation to signify other aspects other than comprehension, such as ownership, coordination of collaboration (e.g. passing content to another collaborator involves orientating it toward them), sharing with a subgroup (e.g. orientating the content to a neutral or shared orientation between users) and mediation of communication (e.g. using orientation to signify specific content under discussion).

One of the advantages of the Digital Tabletop format is that its collocated nature affords face-to-face interaction. This has considerable advantages when working collaboratively. Eden [36] investigates some of these advantages over the more restrictive practice of collaborating in a distance learning context. Face to face interaction allows for greater communication, a real-time understanding of the current state of a task, and of other users interactions. It also allows for greater parallel interaction, rather than turn taking. The kind of interaction on the digital tabletop can also influence communication. Jamil et al. [53] compared touch interaction with a pantograph interaction technique (based on the work by Nacenta et al. [87]). They found that, similar to the issues of territoriality, the "pantograph" interaction technique (where small private actions affect the shared public space) produced less task-based communication behaviours, as users had effectively a private part of the interface for interaction purposes.

Classifying the kinds of behaviours around a Digital Tabletop require an integration of physical interaction analysis and more "usual" communication analysis. Ioannou et al. [52] present an assessment approach for problem based group collaboration around a digital tabletop. They suggest a coding scheme based on proposals and the resulting communication behaviours (with similarities to Barron [7]), which include touch-based gestures and interactions with the digital table:

Cognitive Contributions:

1. Proposing—proposing a new idea or thematic unit
2. Elaborating—clarifying, building on previous statements
3. Negotiating meaning—evaluation of proposal, questioning/answering, expressing agreement/disagreement, providing arguments for/against
4. Stating consensus—summary of ideas, metacognitive reflections
5. Other talk—tool-related talk, social talk, laughter

Physical Contributions:

1. Communicative gestures—show on the table without touching, dominating/blocking gestures
2. Touch gestures—resize, rotate, type, move something across, random touching or touching to explore.

Digital Tabletops in-of themselves do not necessarily lead to better learning. The design of the task must exploit the affordances of the digital tabletop platform. Do-Lenh et al. [33] compared a collaborative learning task (writing a concept map of a document) both on standard computers and on an augmented desktop with tangibles (paper). The study involved 48 university students in 16 groups (8 tabletop and 8 computer). Learners completed the task only once. Learners were tested on knowledge transfer, and it was found that for this task, there was no significant difference in the learning outcome for individuals. There were however differences in behaviour between the two cases. Learners using standard computer setups exhibited more task-focused talk, but weaker learners were less involved, with the talk being explanation-like rather than co-operative. As the authors admit, this study does not show a conclusive result on learning outcome. The design of the table-based task, that is augmented paper based around a desk layout, is arguably not taking full advantage of the digital tabletop format. Interactions are not designed specifically for tabletop use, and other than linking, there is little consideration for mapping table interactions with specific skills required for the higher-level concepts of the task, or any use of scaffolding or explicit separation into subtasks. The study also only had a single iteration – even though there was a training phase, this does not seem sufficient to argue that the users were not still learning the novel interface during the task.

Piper and Hollan [93] also conducted a study utilising tabletops, comparing it to a paper based exercise. The study was conducted on pairs of undergraduate students in the lab, and its aim was to investigate the effect of the digital tabletop on cognition and social activities and the learning benefits gained from tabletops (apart from the novelty factor of new technology). The analysis focuses on the effect of using digital tabletops versus paper rather than the outcomes from the application (which is deliberately simplistic). This approach however does not seem to exploit the affordances of the digital tabletop. By keeping the application deliberately simple, the extra opportunities for scaffolding, interaction monitoring, making required subtasks explicit and visuospatial task design were missed. The study showed that more notes were made by students using paper-based materials, and work was largely sequential. Students using the digital tabletop refined their work more, and worked more in parallel. They also subsequently performed better in exams. They conclude by observing the potential improvements that could be applied to the digital table application – e.g. logging interaction during the session for assessment or reflection, and the potential injection scaffolding by the application.

DigiTile aimed to teach young learners about fractions [73,104,105] and was developed from a single user application (*DigiQuilt*). *DigiTile* requires users to work as a pair to represent fractions by filling a canvas with tiles to divide the total area into specific ratios (e.g. 1/3 red, 1/3 blue, 1/3 green) and the application was particularly suitable to the digital tabletop as it involves spatial manipulation of tiles. The work used learning theory to motivate this transition from desktop application to a collaborative digital tabletop application. Learning theory also informed the design process, and evaluation. The work included a study with pairs of 10 – 12 year olds (on a single table, i.e. not in a classroom context), which generated some interesting results, with learners obtaining a better understanding of fractions using the application. In addition, the amount of collaboration increased as the problem became more difficult.

ArgueTable [123] investigated how a paper based prototype for a collocated collaborative visuospatial task can be realised on a digital tabletop. Users of the application had to externalise their arguments into a visual representations to communicate them with others. The work also separated the overall task into

visuospatial components, showing using this kind of metaphor can work to aid thinking about a typically “non-visual” problem. The work incorporated a short study involving 20 post-graduate students working in groups of 2 or 3 on a single table (i.e. not in a simultaneous classroom scenario). It indicated that perceived awareness of collaborators was increased in a tabletop setting (rather than on computer).

Shaer et al. [119] investigated inquiry-based learning of genomics on the digital tabletop. Their study included 48 undergraduate participants in a university setting and compared existing bio-informatics tools to two collaborative setups, one using multi-mouse and one using touch. Their findings show that the collaborative application improves students’ performance over existing tools and that touch (compared with mouse) shows increased physical participation, encourages reflection, fosters effective collaboration and facilitates greater intuitive interaction.

2.6 Digital Mysteries

The Digital Mysteries task developed by Kharrufa in his PhD thesis [61] and published by Kharrfufa et al. [60] is a Digital Tabletop activity based on the Mysteries paper based task developed by Leat and Nichols [74,75]. The main goal of the task is to examine a body of information separated into data items and then use information to decide the answer to a particular question. It is an activity that has the characteristics of Higher Order Thinking (from Resnick)[101]:

1. Non-algorithmic: path of action is not fully specified in advance;
2. Complex: total path of action not visible from any vantage point (i.e. some internalisation required);
3. Multiple Solutions: with costs and benefits, rather than a "right" answer;
4. Nuanced judgement and interpretation required;
5. Application of multiple criteria, which may conflict with each other;
6. Uncertainty - not all aspects which bear on the task are known;
7. Self-regulation of the thinking process - rather than regulated or coached externally;
8. Imposing meaning - finding structure in apparent disorder.

9. Effortful - takes significant mental effort in elaborations and judgements required.

The question and the data items are designed in such a way that the answer to the question is not entirely determinable from the information data items. This encourages the students to think analytically about the data items and their relationship with each other, performing higher order activities such as grouping and linking data items together, (these are explicit stages in the digital version).

The task also addresses some of the shortfalls of using software as a scaffolding structure through its task design. The task is explicitly divided into stages (reading, grouping and connecting) that focus students on the current sub-task they need to complete. This also allows the software to make some judgments on how correct the student solution to a sub-task is, and provide appropriate feedback at the correct level, such as hints or partial solutions. The kinds of interaction are controlled, so students can only do actions pertinent to the current sub task, and each stage introduces more complex interaction tasks such as grouping or connecting. However, there is still the necessity for an expert to make judgments about when a student is stuck, and to interpret the communication activity appropriately. Also, unlike applications such as webkit [124], the application allows for manipulatable visuospatial representation of ideas, and therefore has more potential collaboration by communicating these ideas among the group.

While several design aspects of Digital Mysteries have been shown to be useful in a collaborative context (visuospatial design, interface freezing and explicit stages), they have not been applied to a task that is usually considered non-collaborative for example, composition of Persuasive documents

2.7 The Classroom as an "In the Wild" Context

Implementing technological interventions in a classroom setting is a greater challenge than simply deploying the technology. Classrooms and schools have physical, social and cultural structures that require careful integration.

2.7.1 The Meaning of "In the Wild"

In HCI, the term "In the Wild" usually refers to evaluating technology situated in an environment as close as possible to the "real world" environment in which the technology would be used if it were a finished "product" [23]. It is a common scenario for testing designs and interventions, adding authenticity, integrity, real world data collection to deployments that can also aid the uptake of technology. "In the Wild" studies often engage with stakeholders and recruit participants early in the process, even in the design stage of the research.

For the purposes of learning applications, an "in the wild" deployment could be in an existing classroom, administered by a teacher. Aside from the technical challenges, this obviously requires co-operation from a school, and a good relationship with the teacher, who should ideally see the advantages of incorporating the application into their own teaching.

One possible way to address these challenges is simulate a classroom context in the lab, i.e. to create "future classrooms" or "computer integrated classrooms" [49] - where computing technology is ubiquitous, such as interactive surfaces on walls and tables, use of sensors to augment objects and furniture [48] to provide input and monitoring for learning tasks. However, such technologies are currently beyond the scope of most classrooms in schools and considerations of how to integrate technologies into existing infrastructures is more important. This kind of solution also bypasses the social and cultural challenges that a school presents.

2.7.2 School Culture

As Barkhuus and Lecusay [6] point out, "Technology can only be designed to sufficiently mediate learning if the structures, both social structure and infrastructure, within the environment are understood". They investigated the use of technology alongside "traditional" teaching equipment in a particularly challenging environment, an urban after-school centre. They identify that in collaborations of this nature (i.e. between a learning establishment and external researchers) the social organisation is negotiated in an on-going fashion and may occasionally break down.

In classroom based "in the wild" studies,, the culture of the school and the approach of the teacher play an important part. Priestly et al. [95,96] characterise school culture as a balance between the prescribed curriculum and teacher autonomy. Highly prescribed cultures have the curriculum largely defined outside of the school (i.e. by national government). This allows easy comparison of student attainment across a large scale (i.e. nationally) and therefore provides a method of ranking school quality. It is however a one-size-fits-all policy, and is inflexible with regard to individual students. At the other end of the scale, where teachers (or schools) have a large amount of autonomy, curriculum is defined at the classroom (or school) level, and can be readily adapted to individual needs. Priestly et al. also characterise the approach of teachers as being a balance between two philosophies, teaching as a way of imparting knowledge and teaching as a way of developing skills. The imparting knowledge approach (i.e. the acquisition metaphor [118]) is characterised by being subject focussed, concerned mainly with attainment, didactic in style and *convergent*. The skills development approach (i.e. the participation metaphor [118]) is largely cross-curricular, concerned with developing transferable skills, based on hands on problem solving and divergent.

Robertson et al. [106] developed the "train the teacher" model (TTM) to handle this process. The model suggests that a teacher requires training in order to use the technology and integrate it into the classroom, including understanding constraints, as well as potential successes. They also state the need to give teachers support and time to learn the technology. The paper focuses on the technical deficit of the teacher in these kinds of deployments, but does not perhaps fully acknowledge a teacher's expertise in the classroom, which researchers may lack.

2.7.3 Orchestration

Integrating a task designed for groups (or individuals) into a classroom is not only an infrastructural challenge, but also raises issues about the teacher's role and their interaction with technology. Orchestration is a metaphor or model describing the role of the teacher in this context. Dillenbourg and Jermann [27] described orchestration as "the real time management by a teacher of multiple learning activities within a multi- constrained environment". Dillenbourg and Jermann describe a number of key characteristics that define orchestration. These aspects

and challenges exist in managing learning in a classroom and affect teachers and learners alike. They are:

1. Leadership - teachers drive the classroom activity,
2. Flexibility – teachers can change the activity and direction of the class "on the fly" (i.e. in real-time),
3. Control – teachers maintain control and interest of the class,
4. Integration – combining individual, group and class level (and beyond) activities,
5. Linearity – sequencing the activities that most students will perform at the same time,
6. Continuity – structuring successive activities around shared elements, such as groups, artefacts, assignments etc.,
7. Drama – managing the emotional state of the class, with periods of high emotional involvement used to engage learners with the rest of the material,
8. Relevance – the time apportioned to a topic should reflect its importance in the curriculum.
9. Physicality – the physical layout of the learning space and activities within it,
10. Awareness – the teacher should be aware of all ongoing activity in the learning space at a behavioural level,
11. Design for all – an orchestration system should be available for all teachers, not only exceptional teachers,
12. Curriculum Relevance – learning outcomes should be important in the overall curriculum of learners,
13. Assessment Relevance – learning activities appropriate to the assessment criteria of the students,
14. Minimalism – activities specific to the learning scenario and that are not provided by books, software etc. already in use by the students and
15. Sustainability – the energy required to run the system can be maintained for many years.

It can be argued that elements 12 – 14 are in fact specifically about the learning activity and not directly a factor of orchestration.

While it is clear that orchestration is required, currently the onus is on the teacher to provide these factors in the classroom. Can the orchestration process be assisted with technology? There have been several attempts at utilising technology to assist in the orchestration process. In particular, digital tabletop based learning activities have been seen as an ideal candidate for incorporating a technically supported orchestration element [1,34].

The *TinkerLamp* project presented in the PhD thesis by Do-Lenh [34] was heavily influenced by the concept of classroom orchestration. As well as the Digital tabletop activity itself (which involved the use of tangible objects on four tables in a classroom), the project utilised several tools to help the teacher in the classroom orchestration. These included a wall display (*TinkerBoard*) that showed groups progress centrally and served not only as a teacher aid but also as a way for learners to self-regulate. It also allowed the teacher to provide reflection by comparing solutions from different groups in a debriefing phase. The teacher did not have a separate private control mechanism; instead, the *TinkerBoard* provided a public space for their orchestration activity.

SynergyNet [1] is a bespoke lab-based environment designed to simulate a classroom. It incorporates four integrated digital tabletops, a digital whiteboard and a separate control surface for the teacher for the purposes of orchestration. This infrastructure has been used in several subsequent digital tabletop learning projects [44,83] (which were facilitated by researchers). The system provides a private remote control system to the teacher through a multi-touch console. Using the console, the teacher can visualise, interact with and control the tabletop screens for each of the students' groups. It also allowed the teacher to display the contents of a group's tabletop on a public display. The study consisted of 12 volunteer participants (children aged 10), and teacher. Children worked in groups of three on the multi-touch tables in the lab while the teacher monitored the learning task from the lectern, while researchers facilitated the session. The results focused on the usability of the system, but also demonstrated several benefits. For example, the non-interfering monitoring capabilities provided feedback to the teacher, and the ability to show a group's work on the public display regulated

progress. The work also found that teacher tended to avoid the use of features that allowed remote interventions in students' activities.

Martinez-Maldonado et al. [78] also investigated technology supported orchestration in a digital tabletop equipped classroom. Their lab-based study involved 236 volunteer undergraduate students over 14 sessions, and its aim was to ascertain how effectively the teacher-planned actions were enacted by the students. The technology automatically captured interactions from the users to provide data for analysis and for subsequent reflection activities. The work emphasises the fidelity of the classroom context, rather than being a controlled environment, with sessions run by, and content designed by a teacher rather than a researcher. The orchestration involved the teacher having control over the tables during the session (blocking, unblocking, sending messages etc.) through an orchestration tool on the teacher's laptop. The tool was designed to be minimalistic so as not to distract the teacher from other teaching activities. There was also a public display connected to the teacher's laptop. The interaction data was also available in real-time to the teacher, allowing them to make timely interventions or monitor progress during the sessions. The study showed that the technology (the tables themselves, the interaction tracking and the orchestration tool) is capable of providing a richer monitoring environment empowering teachers to make real-time decisions in the classroom that would not be possible without it. The work also emphasises however that the benefits are as a result of an involved design process – the learning activity, interaction monitoring and orchestration are designed from the ground up to be complimentary, simply adding the technology to any learning task would not necessarily produce the same benefits.

Unipad, a project by Kreitmayer et al. [68], is a classroom learning activity that runs on shared tablets (per group) and a public wall display. The activity explicitly switches between working on the shared group devices and the classroom public display with the goal being an increase in peer group discussion and empowering teacher involvement through focusing and constraining shared attention at different stages of the activity. Compared to other table-based systems, the system is lightweight and portable, allowing for testing in an in-the-wild study in a school. There is the obvious drawback however; that tablets are not a large

enough shared social space to fully recreate the collaborative affordances of a digital tabletop, and task design for the two platforms would need to be different.

Kharrufa et al. [58,59] provide an analysis of the current work on integrating digital tabletop systems and technology supported orchestration. Their work is based on the study presented as part of this thesis in Chapter 4. They compare some of the projects mentioned with their findings from the study presented in Chapter 4 and define a framework of design recommendations for extending group focussed digital tabletop activities to the classroom setting by exploiting the benefits of orchestration. Their framework is three dimensional – with axis depicting space, time and "planes", where a plane is an organisational concept in the classroom (i.e. student, group, teacher, class etc.). They define learning activities (and their design) as being distributed across the three dimensional volume described by these axis, with the transitions between points in space/time/plane being the key components of the activity.

2.8 Summary

There are two main aims for this work, based on the research questions outlined in the introduction. The first is to produce a collocated, collaborative application for learning Persuasive Extended Writing, and how can the lessons learned from the design process be generalised - thereby answering the research question: "*How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?*" The second aim is to evaluate CCW in a classroom scenario, thereby answering the research question: *"How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?".* This evaluation is based on literature investigated in this chapter that suggests there is a potential learning impact from allowing collaboration in a usually non-collaborative learning setting. It aims to identify and evaluate the collaborative behaviours around CCW based on design elements within the application intended to elicit collaborative behaviours (i.e. visuospatial representations, decision points etc.).

As writing is a wide-ranging domain, CCW should focus on a specific writing sub-genre that is stereotypically challenging for new learners. To this end, Persuasive Extended Writing is shown to be suitable i.e. the genre of persuasive

writing as defined in the Writing Frames exercise [15,76] is a suitable task. Writing Frames provides a structured methodology for teaching this genre, but its current form is not dynamic and largely non-collaborative [15].

The nature of CCW should be grounded in sound pedagogical theory. In particular, the concept of collaboration as a learning mechanism (i.e. socio-cultural learning) is well established [132,140,141]. Based on long standing theories, it has been tested in various scenarios, both with and without technology. What is clear however is that collaboration is not an inherent property of simply bringing learners together. Collaborative tasks must be specifically designed to exploit the benefits of socio-cultural learning, such as rich communication, shared understanding of and interaction with the task. To this end, the concept of Distributed Cognition [89] is a useful starting point. This theory encompasses the basic requirements of collaborative work, and again has been tested in real world situations, including education [29,112].

Visuospatial representations have been shown to be a useful medium for externalising an individual's thoughts and communicating difficult concepts to others [67,89,143]. If those representations can be manipulated by collaborators, they become a useful two-way communication medium. Collaborators can use the representation as an extra channel in their communication behaviour, in addition to their utterances and gestures. This communication is richer in a collocated setting, where collaborators are aware of all the actions of their peers without an intervening medium (such as video or audio feeds).

Digital Tabletops are an ideal platform for this kind of collaborative activity [26,46]. They offer a shared social space and interface (provided physical requirements are met). They are also ideally suited to hands-on visuospatial manipulation activities. Their digital nature also allows for the explicit structuring of tasks, logging of interaction and injection of scaffolding by providing real-time assessment of task progress.

Given these factors, it is appropriate for the collocated collaborative learning writing application to be situated on the digital tabletop and devise a visuospatial metaphor (or series of metaphors) for the writing task. Chapter 3 describes a learner centred design process [41,122] that details the creation of a collocated collaborative learning application for writing.

As identified above, there are two key tools that are particularly influential in the design of a collocated collaborative writing application. Digital Mysteries [60] provides an ideal prewriting exercise, and the design uses similar philosophies to those discussed (i.e. visuospatial representation, interface freezing and explicit stages). Writing Frames [76] provide a basis of a planning stage, with specific genres (such as persuasive writing) and the appropriate structures.

Mapping these tools onto the diagram devised by Coffin et al. [20] shows their role in the overall writing process (note there is some potential overlap from Digital Mysteries into the planning stage) (Figure 3):

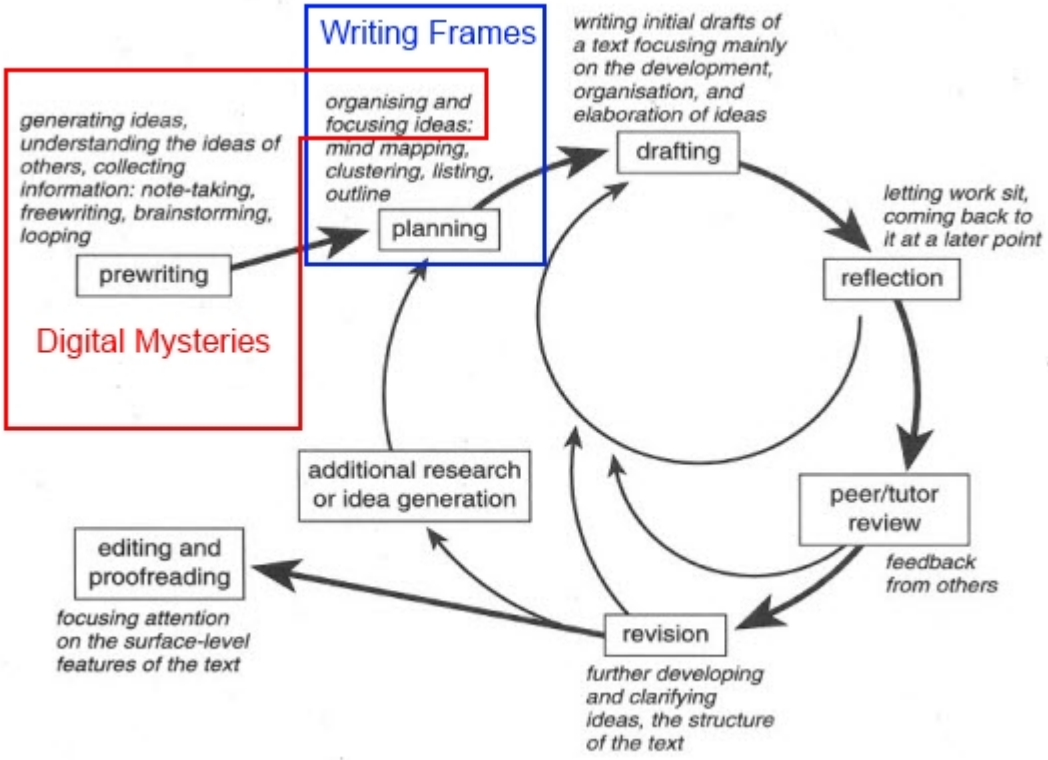


Figure 3: Coffin et al. Writing Process - Including Digital Mysteries and Writing Frames.

To answer the second research question *"How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?"* the initial design also requires authentic "in the wild" testing. This means deployment in a classroom in a school, with sessions run by teachers, using content designed by teachers. In Chapter 4, a deployment is described that aims to fulfil this requirement. This is still part of the design process as well as being an evaluation, and indeed several issues with the classroom deployment occurred,

both in CCW design and in the approach to the deployment itself – expectations from all parties (teachers, researchers and students) were not fully explored. Chapter 5 is concerned with a second deployment in a different school, where application design and research approach are refined, based on a greater understanding of all parties' expectations of the study.

Chapter 3

Initial Design

The first research question outlined in the introduction, *"How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?"* requires an answer both rooted in the literature discussed in Chapter 2 and a design process that incorporates the input of learners. To this end, the following chapter described a learner-centred design process [41,122] across three iterations, beginning with an initially open design to first of all identify the behaviour of learners in a loosely structured learning task. The subsequent iterations then become more structured as key sub-tasks are identified. The final design, and the process that created it, form a proposed "hypothesis" to attempt to answer this research question.

3.1 Aims and Requirements

The purpose of the Collocated Collaborative Writing Application is to help participants in learning how to produce Persuasive Extended Writing. It should be suitable for small groups of novice users to learn the process of creating structured documents by exploiting the learning benefits of collocated collaboration outlined in the literature. It should also address the research objectives "Produce and test a candidate design to ascertain if designed-for collaborative behaviours occur" and ultimately "Produce guidelines that may be utilised in the general case". The initial approach builds on key points on collaborative learning and designing collaborative applications from the literature.

Collocated collaboration has significant pedagogical benefits [92,132]. Working together encourages learners to externalise their thoughts, clarify their understanding of concepts and come to a shared understanding through social interaction. In supporting collaboration, it can be beneficial for learners to be able to communicate their knowledge and understanding visuospatially. The benefits of using shared visuospatial representations include reduced cognitive load through externalisation, a deeper understanding of the problem through re-representation and a means of distributing thoughts and ideas between collaborators [67,89].

The design of the writing application has two main aims: Firstly, to convert the Extended Writing task – a task that is normally non-collaborative and not particularly visuospatial - into a collaborative visuospatial task. Secondly, the writing application should exploit the pedagogical and cognitive theories outlined in the literature – it should aid collaboration and it should incorporate scaffolding elements into the activity to aid learning.

The initial design should tie specific elements to the learning, collaborative and cognitive behaviours that the process aims to elicit from the participants. The design goals for the Extended Writing application are therefore to repurpose Writing Frame-based Extended Writing as a collocated collaborative visuospatial task thereby incorporating:

- Collocated communication, i.e. discussion about the task;
- Visuospatial interaction that:
    - Promotes representation & communication of ideas;
    - Promotes externalisation of thinking;
    - Helps decision making;
    - Reduces cognitive load.

This initial design was tested with participants (from the target age group for the activity) and the design was iterated based on observations of the participants' interaction with CCW and each other. The writing application was refined through three iterations – CCW Versions 0.1, 0.2 and 1.0.

3.1.1 Collaborative Planning and the Writing Process

CCW will be primarily designed to allow for collaboration during the writing process, specifically in the *planning* stage (i.e. to accomplish the same goals as the Writing Frames paper based tool [76]). To this end, the planning stage of the writing process presented by Coffin et al. [20] can be expanded to incorporate the idea of collaboration (Figure 4):

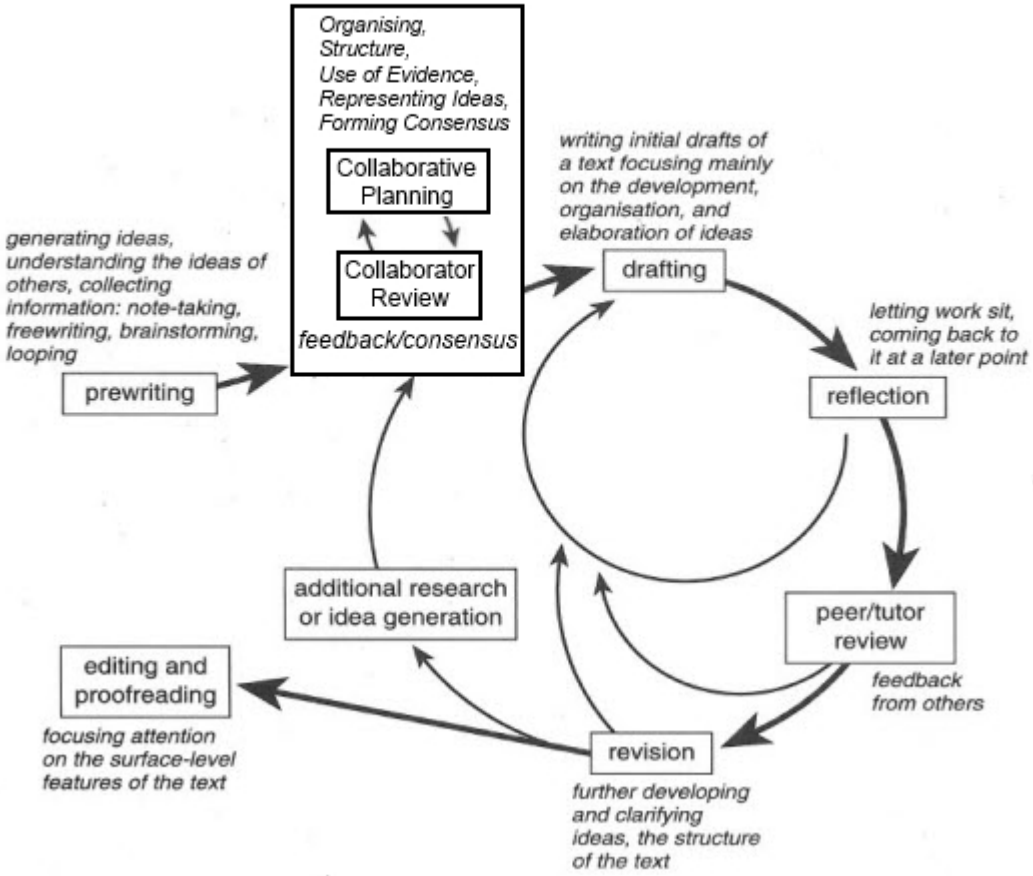


Figure 4: Coffin et al. Writing Process - Collaborative Planning Stage

The expanded planning stage now incorporates its own *internal feedback loop*, i.e. collaborators, through the collaborative process, are refining the planning process and coming to a joint consensus about what the plan should contain. This internal loop allows for some of the effort that would come later in the process to be applied directly in the planning stage (though it does not replace this effort completely, reflection and review can still occur outside this stage). Situating the collaborative feedback closer to the actual activity in the cycle could have benefits, such as remembering the activity in more detail when feedback is provided, focussing feedback on the planning activity, agreeing a consensus before moving onto later stages and generally improving the later stages by producing more rigorous plans.

3.1.2 Collaborative Writing as a Visuospatial Task

The first of the aims, to make a visuospatial representation of the Extended Writing task, requires that suitable visual metaphors be identified for key components (subtasks) of the task. In order to decide what would constitute a suitable subtask, some thought is required about how it might be used to regulate a collaborative setting. As indicated in Distributed Cognition, during collaboration parts of a task can be accomplished with various levels of participant interaction. In the case of a group working at a digital tabletop, these include: in parallel - by simultaneous interaction; singularly - when a user takes ownership of a shared resource that is limited to a single user, e.g. a keyboard; or forced – when users are intentionally brought together to make a joint decision. Ideally, subtasks should specifically facilitate a particular level of collaboration.

Extended writing documents suggest an obvious separation into paragraphs. Current Extended Writing activities, such as the Writing Frames teaching method [76] expand upon this initial separation: the document is first subdivided into paragraphs or sections, and elements such as connecting words are separated out from the main text. However, in Writing Frames the structure is already fixed - in order for users to be able to represent their thinking with more freedom (i.e. visuospatially), the paragraphs should be flexible and movable. This allows the participants to arrange them in order to aid cognition (e.g. externalising their thoughts for others to see). The structure of the document also depends on how the paragraphs connect together, so an extra element is required to represent how particular paragraphs connect to each other. In addition, there needs to be some way of visualising key elements of the paragraph (aside from the text of the paragraph), such as incorporating evidence or themes into the paragraphs.

Designing CCW in a visuospatial manner also allows for appropriation by the user [31] – that is users can use the elements of the design to make representations of their own choosing that are not envisioned in the original design space.

3.1.3 Promoting Thinking and Learning

Making the task visuospatial allows the design to exploit the aspects of pedagogy and thinking outlined in the collaborative learning section (2.3) of chapter 2, in

addition to affording collaboration by allowing users to interact with different parts of CCW in parallel. The interface interactions tie in closely with Distributed Cognition. At the group level around the tabletop, participants are located together, making communication of the state of the task easier. As the participants are using the same interface, the interface itself can be the communication medium of the current state of the task - the interface should represent the current state of the task, and users' actions need to be clear and have consequences that affect the state.

The design should encourage externalisation of thinking through the interface, through data and relationship representation (e.g. including keywords and evidence in paragraphs, sequence manipulation and connection of paragraphs, the creation of annotation notes etc.). It also promotes discussion and sharing through forced decision points (e.g. naming connectors, naming paragraphs, deciding when the group is finished etc.). Externalisation increases the probability of useful, task-related discussion and these elicit useful learning mechanisms [26,63].

3.1.4 Functionality

In order to construct a structured document, users must be able to execute certain required actions. From an initial representation of the evidence data, participants are able to perform these actions to construct a visuospatial representation of their document. These actions are universal across all iterations:

3.1.4.1 Paragraph Creation

Participants can create empty paragraphs. Paragraphs have a title, indicating the theme of the content of the paragraph. Optionally, the paragraph may also be associated with a "thinking hat" [12] in order to prompt specific language style within the paragraph. "Thinking hats" are a way of describing the style of language used.

3.1.4.2 Paragraph Connectivity

Participants can create a connection between two paragraphs. Connectors are labelled to show the relationship between the two paragraphs, typically using joining words or phrases (based on Writing Frames).

3.1.4.3 Annotation

Participants can create notes to annotate their work.

3.1.4.4 Include Evidence in a Paragraph

Participants can include provided evidence data items in their paragraphs, or create their own. This allows them to show the relationship between the evidence (data items) and the text of the document. The evidence data items are presented to the participants in several views; an ordered index, a series of outlines, and in the final configuration of a completed digital mystery.

3.1.4.5 Generating Text

Participants can also type text into paragraphs. This is something that requires consensus between the group members, as there is only a single keyboard.

3.1.4.6 Progress Mediation

Participants self-assess if they are finished their document (or current stage). If all participants agree they are finished, CCW checks their document against several criteria (word count, number of paragraphs, connectivity and balance across paragraphs etc.). If any criteria are not met, a help note is created explaining the problem, and the users are asked to continue. The help notes have three levels (per criteria) that explain in more detail what the problem is and why solving it would produce a better final document.

3.1.5 What to Write About: A Shared Activity

In order to produce a collaboratively written document, students must first have some shared experience or activity about which to write. For example, the shared task could be a lesson or activity delivered in a classroom, or some shared research project. The task should be a shared activity that all the students have participated in, that can be separated and thought about as a set of components and is sufficiently large or complicated that stimulates writing, i.e. has some or all of the characteristics of Higher Order Thinking [101].

3.1.5.1 Digital Mysteries as a Shared Activity

The mysteries task, both the paper version [75] and the digital version [60] (Figure 5) is a suitably complex shared activity, involving higher order thinking skills. The Digital Mysteries task is examined in detail in section 2.6, but in summary:

- The goal of the task is to examine a body of information separated into data items in order to decide an answer to a particular question.
- The question and the data items are designed in such a way that the students have to think analytically about the data items and their relationship with each other.
- The task is performed collaboratively in a small group, i.e. it is a shared activity.
- The task requires significant higher order thinking and takes a reasonable time to complete.
- It is visuospatial, and "data slips" can be re-used as "evidence" in the writing task.

Digital mysteries also provides a model for designing the software for the writing task - specifically Distributed Cognition and the use of software tools to externalise thinking in order to re-internalise in an "ordered" form later. It also uses the affordance of a tabletop interface to facilitate collaborative working.

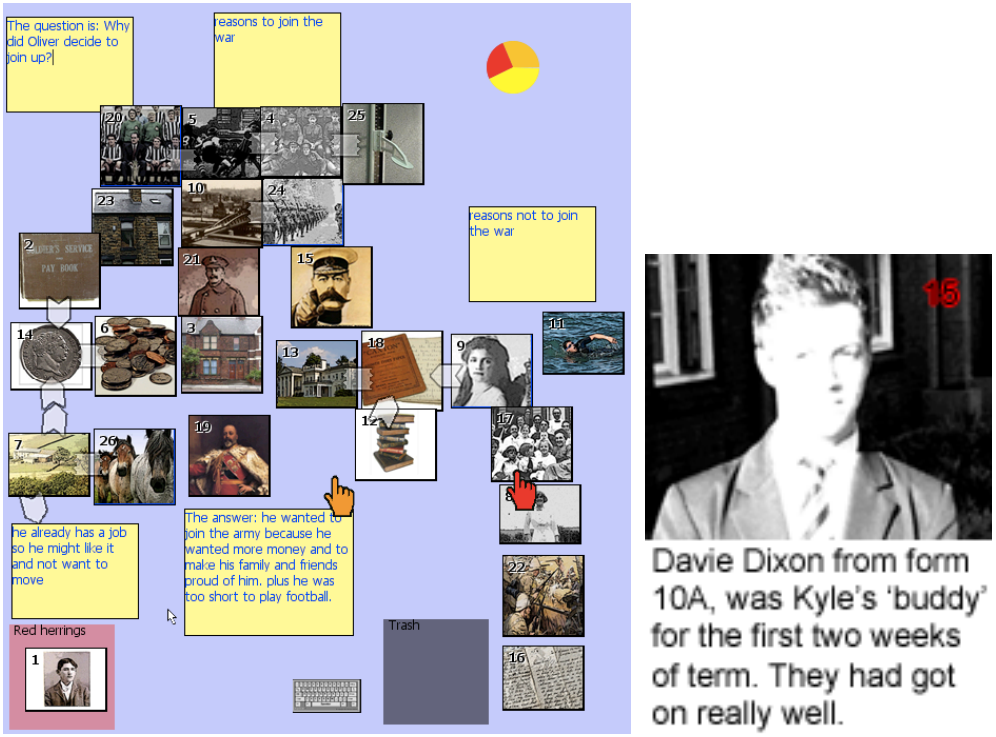


Figure 5: a) Digital Mysteries – showing "data slips" (pictures), notes (yellow boxes) and connectives (sticky tape) and b) an example "data slip" that can be reused as evidence in the writing task.

The Digital Mysteries task also addresses some of the shortfalls of using software as a scaffolding structure through its task design. The task is explicitly divided into stages (reading, grouping and connecting) that focus students on the current sub-task they need to complete. This also allows the software to make some judgments on how correct the student solution to a sub-task is, and provide appropriate feedback at an appropriate level, such as hints or partial solutions. The kinds of interaction are controlled, so students can only do actions pertinent to the current sub task, each stage introduces more interaction types such as grouping or connecting. The task aims to find a balance between open interaction and a scaffolded structure. While CCW shares some design aspects with Digital Mysteries (visuospatial design, interface freezing and explicit stages), it does not apply these to a task that is usually considered non-collaborative. In the case of CCW this is planning and composition of Persuasive documents.

3.1.6 Mapping CCW to the Writing Process

The initial design for CCW incorporates the collaborative planning stage outlined in the modified diagram above (Figure 4), as well as the capacity for generating text for a draft version of the document (Figure 6).

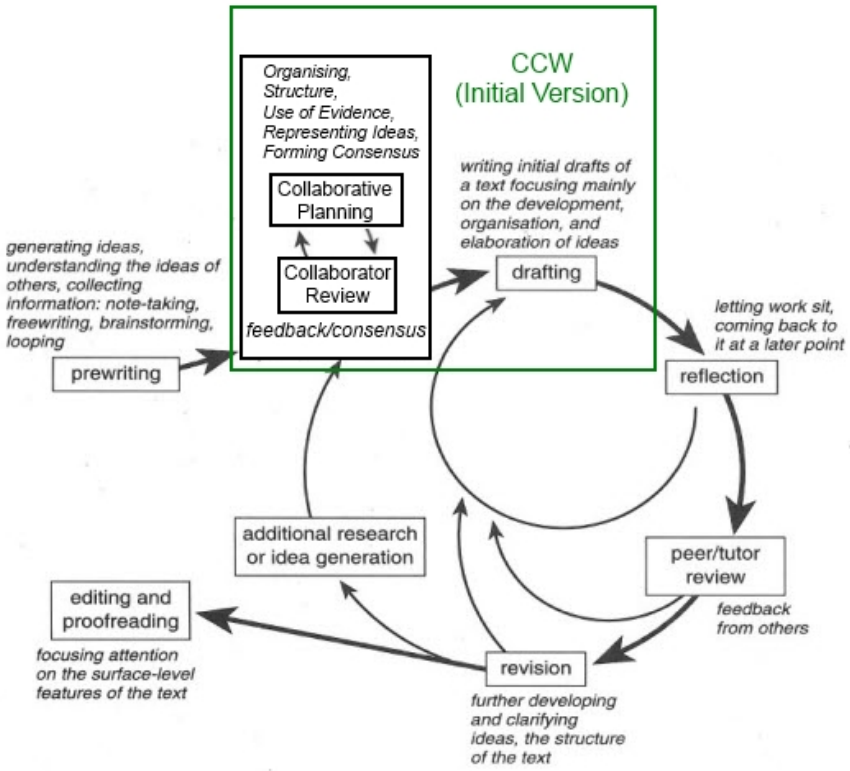


Figure 6: Coffin et al. Writing Process with CCW

3.2 Learner Centred Design

CCW's development utilised a learner-centred design process [41,122], the aim of which was to refine the design with the input of learners, in order to produce an application more suitable for a larger classroom based study. This was not, however, a full participatory design [97,98]. Learners were presented with a "complete" application, and were not directly involved in the design process. This initial implementation supported all functionalities from the beginning. This was then refined based on observation, learner feedback and an examination of the results of the task. The design was further refined based on two in the wild studies, outlined in Chapter 4 and Chapter 5.

3.2.1 Design Iterations Protocol

Learner centred design iterations took place in two parallel strands. For both strands the task involved two separate sessions: i) the completion of a Digital Mysteries task (mysteries used are available in Appendix A: Digital Mysteries) which takes around 1 hour to complete, and ii) the Collaborative Writing Task (around 1 hour). There was a break of 1 hour between sessions. For each session, the participants consisted of a group of three individuals aged between 13 and 15 years old. The hardware used was a Promethean ActivBoard Digital Tabletop. This is a pen-based table, which allows identification of users and allows users to touch or rest on the interface without affecting CCW. Two researchers observed all sessions. In addition, sessions were videoed and audio recorded. The system recorded users' interactions and groups took part in a short (5–10 minutes) semi-structured interview after each session. The intention was that one group would be consistent through all iterations, but that there would be an n additional group per iteration to give a newcomers perspective. One group (Group B) completed all three iterations. Group A completed iteration 1, and Group C completed iteration 2. (Table 1):

Iteration 1	Group A	Group B
Iteration 2	Group C	Group B
Iteration 3	-	Group B

Table 1: Group Participation

	Iteration 1		Iteration 2		Iteration 3
	Group A	Group B	Group C	Group B	Group B
Planned Paragraphs	3	2	4	4	5
Total Paragraphs	4	4	10	6	5
Slips (Added - Removed)	3 (6 - 3)	7 (10 - 3)	8 (11 - 3)	6 (13 - 7)	12
Connections	3	9	12	9	4
Time Planning	< 1 min	< 1 min	14:12	06:07	14:35
Time Structuring	n/a	n/a	09:04	05:40	03:29

Time Typing	n/a	n/a	36:32	38:56	30:49
Time Total	23:13	1:03.00	59:48	50:43	48:53
Average Paragraph Length	n/a	64	42.25	65.75	52.40
Document Length (words)	n/a	256	169	263	262

Table 2: Results Summary

3.2.2 Iteration one: Design and Rationale

The initial implementation is as open as possible; all the actions (paragraph creation, evidence insertion and paragraph connection) were available from the beginning of the task without restrictions. The intention was to use this first implementation with learners, to observe their behaviour and the outcomes from their task to look for improvements in the subsequent iterations. Specifically, the intention was to observe areas in CCW (version 0.1) suitable for decision points and scaffolding (where the learners skipped key subtasks or did not discuss them together).

In addition, learners could create "notes" to annotate their work. Users could create paragraphs, notes and connectors from a menu. A gestural menu system, based on the Attribute Gates system[126], allowed the selection of actions, as well as the manipulation of objects (e.g. resizing and rotation).When creating a new paragraph or connector, users must decide on their initial contents together. As in Digital Mysteries, evidence is represented as visuospatial, manipulatable data items. By including an evidence slip in a paragraph (through dragging a slip from the index tab) meta-data about that slip is automatically inserted into the paragraph (Figure 7). A document window shows the current text of the document, so when text is typed into a connected paragraph it also appears in the document.

In addition, in this first iteration, the writing application begins with a "planning" screen, in which users can decide how many initial paragraphs to create, along with their initial opening text (a single line of text). When the users have finished the document, a short reflection stage is presented to them showing the document window with their incremental changes over time.

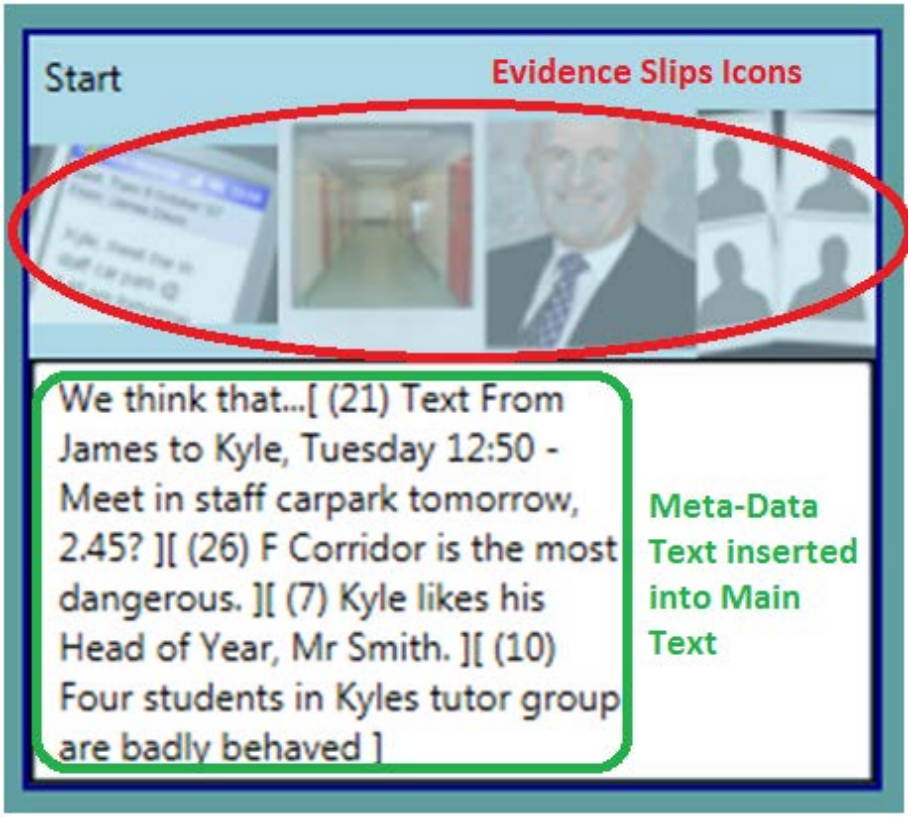


Figure 7: Paragraph with evidence and metadata. Evidence slip icons are inserted into group panel while meta data text is added to the main text

3.2.3 Iteration one: Reflections on Design

Both groups who completed this iteration (A & B) spent very little time in the planning stage, preferring instead to create paragraphs within the "main" application. The design of the software meant that the plan was "lost" after the initial stage (i.e. it is not explicitly represented in the main application). Interestingly, despite not completing the planning phase, group B proceeded to use notes to effectively write a document plan within the main application.

Both groups also began typing into the document from the beginning, without giving detailed consideration to the structure of the overall document, or even deciding on the number of paragraphs. Group B, despite their use of notes to make an outline, wrote their whole document in a single paragraph and only when prompted by the researcher did they make small introduction and conclusion paragraphs.

Another problem was that scaffolding was only introduced at the end of the activity when a group decided that they had finished. Consequently, it was only at the end of the process that they realized they have made some poor decisions

earlier, such as only making a single paragraph. Likewise, neither group used the evidence data items effectively, either ignoring them or only adding them at the end when the criterion (number of paragraphs created, length of document etc.) were not met.

Despite the fact that paragraphs were fully rotatable, neither group changed the angle to allow different members of a group to read them from their different vantage points around the table. Team members seemed happy to read from the side, or stand around the same side of the table to read, finding it easier to move themselves rather than rotate the paragraphs.

The reflection stage, along with the planning stage, was little used (see Table 2). Due to the nature of the reflection stage, i.e. it only showed text typed into the document that the users had connected properly; a full picture of the task was not made apparent to the learners. It might have been useful for learners to see their intermediate spatial representations of their paragraph and evidence usage during reflection in addition to the text.

Although the design attempted to incorporate planning as a separate initial stage before the main application, the groups did not engage with this and skipped ahead. Once in the main application, however, one group appropriated the notes tool to generate a plan. In the next iteration, the design was amended to better integrate the planning process into the main visuospatial application.

3.2.4 Iteration Two: Design and Rationale

The planning stage was underutilised by the users in the first iteration. For the second iteration, the planning phase was moved into the main application, and to allow more freedom as to what a plan could contain. Therefore, paragraphs had an added "outline" textbox that allowed users to write an outline as well as the main text for each paragraph. Outlines were added to the paragraph creation window when a new paragraph was created (Figure 8), so users had to think about how they would use a paragraph at the point of its creation. Outlines were visible as long as the paragraph was maximised (i.e. full size) and an extra outline window (mirroring the document window) that showed the whole document outline was added, reducing the likelihood that the plan would get "lost" (Figure 9).

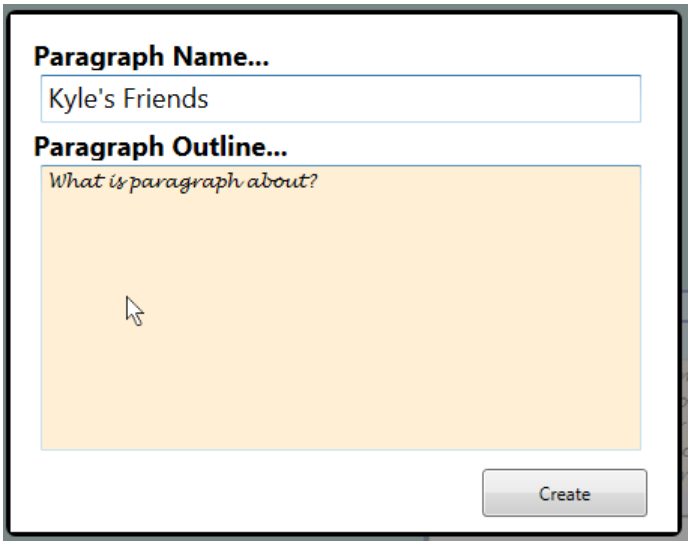


Figure 8: Adding outlines to paragraphs. When a paragraph is created, users type a description of what the paragraph should contain

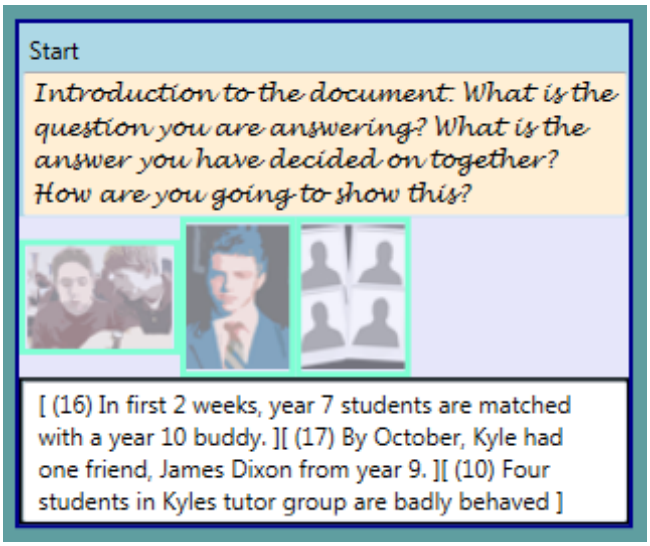


Figure 9: Paragraph outline separate from main text. Paragraphs now contain the initial outline text separate from the main text.

To counteract the problems of skipping or rushing through important subtasks, CCW (version 0.1) was amended (producing version 0.2) to explicitly separate the process into stages. Digital Mysteries [60] provides guidelines for separating a task into stages in order to regulate progression and provide opportunities for scaffolding. Even in non-learning scenarios, the separation of a large task into subtasks allows users to focus on parts of the problem as needed [29]. This structuring was implemented through decision points, where each group member had to agree they were ready to progress to the next stage together – at these points in the process all other parallel interaction is suspended, forcing the

group to focus on the decision together, and encouraging discussion. However, it is important that this separation into stages should not remove functionality, so that actions can be revisited when necessary.

The students' work had to pass certain criteria before they could continue (a paragraph creation, connection and text entry stage). Again, each stage required the learners to collectively assess and come to an agreement that they were ready for the next stage. This allows scaffolding to be available closer to the error points, and made sure the learners' focus was drawn to key points in the document construction process that previously they had a tendency to overlook.

3.2.5 Iteration Two: Reflections on Design

While the Extended Writing process (as reported by the learners and observed by researchers) improved in the second iteration in that more paragraphs were created, more evidence used and more relevant connections made (see Table 2), there were still a number of aspects of CCW version 0.2 that required improvement.

The outline feature made the need for planning more explicit, but both groups (B and C) were confused about what and how much they should be writing for an outline, and in some cases, they wrote more in the outline than in the main text of the paragraph. It was also confusing for the learners that the evidence data items were associated with the main text but not really with the outline, which led to low levels of data item usage overall (Table 2).

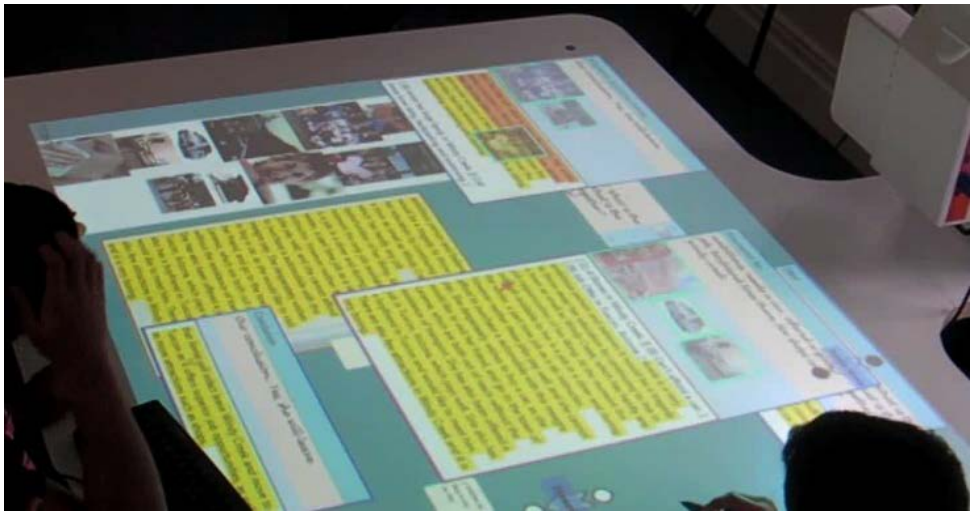


Figure 10: Cluttered, overlapping element of the interface

Screen space became an additional problem within this second iteration – with the addition of outlines to every paragraph and a separate outline and document window, the screen became quickly cluttered and confusing. (Although both groups stated that they did not find the screen space confusing, it appeared to be the case to the researchers observing the session as illustrated in Figure 10). This was particularly apparent during the connection stage, which was already poorly understood by the users (i.e. it was hard for them to associate the text of the connectors with the text of the paragraphs, as they were visually quite separate, they were seen as simply a way of chaining the paragraphs together). Again, neither group made use of the functionality that allowed paragraphs to be rotated, even with the more cluttered interface. In addition, despite the enforced stages, the reflection stage still did not present a sufficiently comprehensive picture of the process, concluding that the reflection stage should show more of the visuospatial manipulations of the learners rather than just the text generation.

3.2.6 Final Design

The final design of CCW – version 1.0 - was informed by the shortcomings of previous iterations while maintaining the features stated by Dillenbourg & Evans [26] and Scott et al. [116] outlined in section 2.5. In addition to the features incorporated in the previous iterations, the final design's interface also shows the current state of the task at all times. The process is additive, meaning that all previous completed actions (i.e. actions that have not been explicitly "undone" by users) are visible in the current state. This means that at a glance, an observer can see what the users have done previously in the task, and where they may have missed some actions.

3.2.6.1 Stages

As in the second design iteration, the task is separated into stages, where each stage is designed to enforce a key element of the Extended Writing process. These stages are Paragraph Creation; Outline Creation & Planning; Connecting; and Typing. Each stage adds more functionality and does not remove functionality from the previous stage(s). Users self-assess when they have finished a stage (by selecting from the menu and agreeing at a decision point), and if they have met the required criteria they proceed to the next stage. If the participants do not meet the

criteria, CCW (version 1.0) offers scaffolding in the form of a help note; feedback suggesting what might be wrong. Help is graded so that repeated failure leads to help notes of increasing specificity and include detailed reasoning about why the criteria is important, (e.g. level one: "you need more paragraphs; level two: "more paragraphs would produce a better structure for your document"; etc.) Having differing levels of scaffolding also means that CCW (1.0) automatically provides scaffolding based on their interaction with the table, but also allows scaffolding to be pre-configured based on prior knowledge of a group's expected performance level [141].

3.2.6.2 Paragraph Creation

Paragraphs were designed so that the outline points (which are now bullet point based rather than purely textual), and paragraph text, are displayed side-by-side rather than one above the other (see Figure 10). Generally, the groups worked with the digital tabletop so that it was in a landscape orientation relative to where they stood, so it seemed sensible to sacrifice horizontal space rather than vertical. Creating a new paragraph from the menu invokes a decision point at which the group has to decide together on a name for the paragraph.

3.2.6.3 Including Evidence

The outline process now associates the evidence data items and keywords with a paragraph outline rather than the paragraph text. The outline is a series of short bullet points (rather than a text box); with instructions to create at least two points per paragraph, (users could add more). When adding a slip to a paragraph, it creates a new outline point rather than inserting in to the main text. It would be up to the users to refer to this in the main text. Users can also type keywords as evidence.

3.2.6.4 Creating Connections

To connect paragraphs, a paragraph is moved onto another one, rather than having a separate connector object. Placing one paragraph over another places it subsequently in the structure, the paragraphs are then locked together. Paragraph ordering creates a decision point where users have to decide what word or phrase would connect the two paragraphs. Once decided, this is displayed directly in line

with the main text of the paragraph. This structure renders the separate document and outline windows unnecessary, as they are effectively on the screen as the two columns of paragraphs. However, it removes some freedom about how the structure is laid out, with implications for viewing the document from multiple angles, and maintaining the visuospatial representation created by users. However, even in cases where the learners worked from three sides of the table, they preferred not to rotate the text, and as the paragraph structure also separates the text into small sections text reading appeared not be an issue [139].

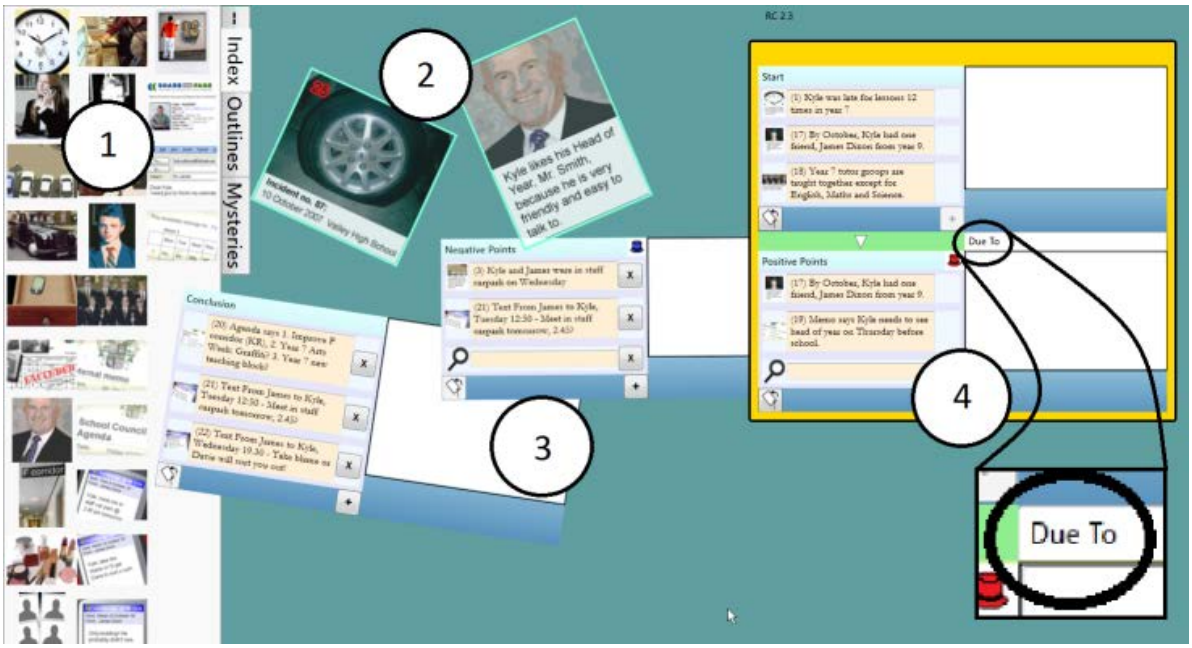


Figure 11: Collaborative Writing Interface: 1. Evidence Palette from which users may Create Evidence. 2. Evidence Data items ready to be added to Paragraphs. 3. Paragraphs, already containing some Evidence, 4. Connected Paragraphs (showing Connection Text "Due To").

3.2.6.5 Using Collaborative Writing: A Use-Scenario

Three learners, Alice, Bob, Claire take part in the exercise. They first complete a Digital Mysteries [60] exercise, working together to come up with their answer as a connected representation of the data items. They then move onto the collaborative visuospatial writing application, where they will write a document to persuade the reader that they have solved the mystery.

After entering their names, CCW 1.0 presents the group with the instructions for the first stage: creating paragraphs and inserting evidence. The learners are required to agree in order to proceed (by touching named buttons). The interface (Figure 11) allows the group to select evidence data items (based on

the data items from the Digital Mysteries) from a palette. They can also view their final mystery representation if desired. The activity begins with two paragraphs, “start” and “conclusion”. Alice decides to create evidence by selecting evidence from the palette that supports their opening argument, while simultaneously Bob creates evidence for the conclusion. Evidence data items are visuospatial elements that can be manipulated to make representations. At the same time, Claire and Bob arrange the paragraphs and add the evidence (by dropping an evidence slip onto a paragraph). The group works in parallel but each member is aware of each other’s actions through the shared interface. Bob selects ‘create paragraph’ from the menu, which freezes the interface and produces a dialogue box. This is a decision point, bringing the group back together again. Decision points help regulate the task, and bring the group together. The group discusses what the new paragraph should be called. Once the paragraph (“positive evidence”) is created, the interface is unfrozen and the group continues. The paragraph becomes a visuospatial element that can be used for thinking and representation. After another paragraph (“negative evidence”) is made and populated with evidence, Claire arranges the paragraphs in a sequence as an informal representation of the document, and then decides from the menu to move to the next stage. Another decision point appears and the group needs to agree to continue (or cancel).

The next stage (connecting paragraphs) is introduced, with instructions. Bob connects the “positive evidence” to the “start” paragraph by dropping it onto the “start” paragraph. This brings up another decision point – a dialog asking for a connecting phrase to go between the paragraphs (to show the learners comprehension of the relationship between the paragraphs). After group discussion, Alice types the word “due to”. Similarly, the group connects the other paragraphs, and Claire selects the next stage (text entry) from the menu.

In the final writing stage, Bob decides there is another paragraph that can be added, and selects “create paragraph” from the menu. After discussion, the new paragraph is created and named “other issues”. Appropriate evidence is inserted and the new paragraph is connected to the other paragraphs as before. The group then plans what text to include in each paragraph, which (as the paragraphs still shows the evidence they chose to include) contains references to the evidence to strengthen their persuasive argument. Finally, Bob selects ‘Finished’ from the

menu, and the group agrees to complete the exercise by writing the document in full based on their collaboratively agreed structure.

3.2.7 Final Design: Main Findings

Only one group (B), who had previously completed the other iterations, undertook the third iteration. Their use of the outline and planning phase was observed (and reported) to be much better than in their previous sessions, evidence used more readily and correctly referred to in the main text (Figure 12).

The paragraph structure was readily apparent (see Figure 12), and clearly showed the progress of the document. Having the outline points and the document side-by-side made it easier to relate the document to the plan, allowing more ready evaluation of task progress and deviations from the plan (i.e. spot documents that do not follow the plan, documents with short paragraphs etc.). Apart from the benefits this affords to observers (e.g. teachers or classroom assistants in a real-world deployment), learners stated that the new fixed structure was easier to create and follow. The observable nature of the state of the learners' progress should make the task easier for a teacher to regulate in a classroom environment, where multiple groups would be working on the task. The disadvantage of having the text in a more rigid single viewpoint did not seem to be a significant factor, though this may be more of an issue if learners were sitting rather than standing, or when working on larger documents. It may also be an issue for groups showing slower progress, whose initial visuospatial representations are transformed, potentially causing confusion. For longer documents, there may also be a need to allow parts of the document to be hidden, by either moving off the screen or minimising finished sections.

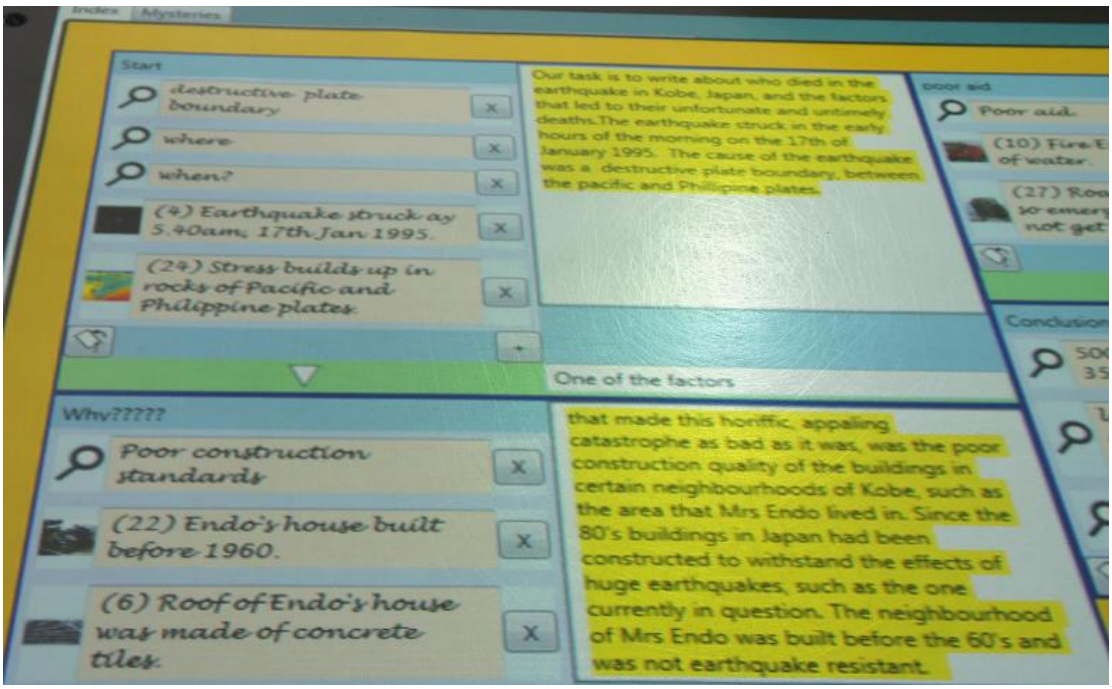


Figure 12: Final iteration document layout. Observers can see all components of the document, including evidence usage.

3.3 Discussion

3.3.1 Overview

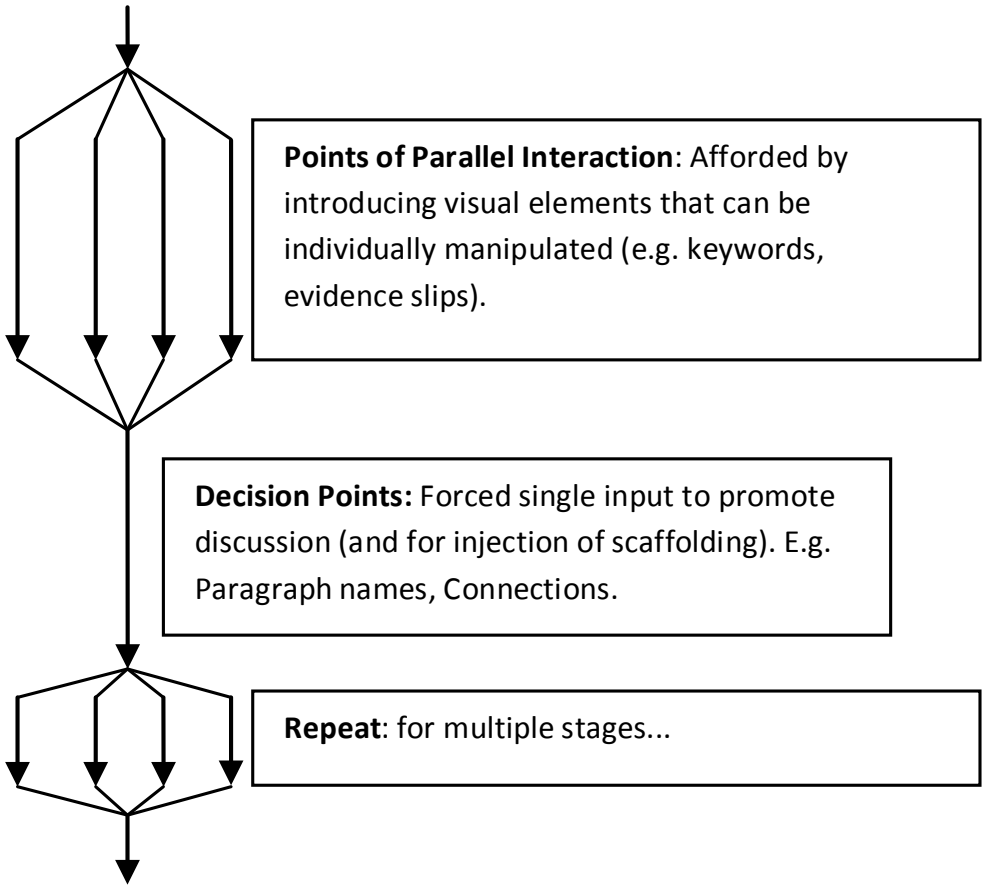


Figure 13 : Interaction Process

The development of Collocated Collaborative Writing forms a proposed answer to the research question, *"How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?"* and incorporated an iterative learner-centred design, producing a collaborative visuospatial tool for learning Persuasive Extended Writing. This required converting a non-collaborative, non-visuospatial task, in this case Persuasive Extended Writing, into a collaborative, visuospatial one. Subtasks were chosen in order to regulate collaboration – that is the subtasks are designed to be completed with learners able to work in parallel, but at key points where the group *needs* to come together to make a decision, parallel action is suspended in favour of a decision point (where the group must agree in order to proceed), i.e. Figure 13. There are potential risks with this strategy, as it may affect learner concentration or flow when they are interrupted. Elements of the task have visuospatial

representations for which the digital tabletop provided an appropriate environment for their manipulation and transformation.

The final design incorporated three stages: Paragraph Creation; Outline Creation & Planning; and Connecting and typing the document text with reference to the evidence used. Visually, the interface produced a cumulative representation of the progress of the learners, culminating in a representation of the final document that incorporated all the decisions made to produce it. This is beneficial in a learning environment where it enables educators to base their feedback and assessment not only on the outcome, but on the process as well. In a classroom environment where teachers have to provide scaffolding to a number of groups at the same time, this type of visualisation can be particularly beneficial and more practical than alternatives that focus only on the outcome.

3.3.2 Designing For Visuospatial Learning Tasks

During the design process, several aspects of the design lent themselves to a more general application. Lessons learned from creating CCW (across versions 0.1 – 1.0) for the collaborative writing task can be abstracted for repurposing non-collaborative, non-visuospatial learning activities as collocated collaborative activities at a digital tabletop, and thus potentially applied to less structured tasks, such as creative writing or creative activities such as music composition. To do so requires designers to pay particular attention to three aspects of the problem and process:

1. the creation of visuospatial elements of the task;
2. through iterative prototyping and evaluation the appropriate balance between structured and unstructured interaction can be appropriately achieved;
3. The division of the activity into meaningful stages and decision points that promote collaboration.

3.3.2.1 Task Focused Visuospatial Elements

Subtasks consisting of visuospatial elements afford collaboration and increases awareness of action (collaborators are more aware of each other's externalised thinking and task progression). Having a shared concept of the task and the processes within it is a key tenet of Distributed Cognition. However, the choice of

what constitutes a visuospatial element should not be arbitrary (or indeed exhaustive) – it should be based on the goals of the activity. The persuasive writing task could have been broken down into many different visuospatial elements, such as paragraphs, connectives, sentences, words, evidence etc. The elements that were chosen (paragraphs, connectives and evidence) were directly informed by the intention of the task. From the outset, the purpose of completing the task was to learn the use of these specific elements, with less focus being placed on language, sentence structure, etc.

3.3.2.2 Structure vs. Unstructured Interaction

Within a learner-centred design and prototyping process, initial prototypes should avoid imposing undue structure on the nature and order of learners' interaction – and instead allow multiple different (but correct) approaches to be explored. This has the effect of shedding light on aspects of the tasks that are not being performed as intended, or are not being given the correct importance with regard to the overall task, for example, inclusion of evidence in our Extended Writing application. These neglected elements that are not being used as planned can be redesigned, combined, omitted (if not important) or explicitly enforced (if they are important for the overall task). Adding structure by splitting the task into stages ensures that a particular area is given the required focus and effort, but should be used minimally, i.e. for areas that are integral to the overall task.

3.3.2.3 Decisions Regulate Collaboration

The task or process, provided it is non-trivial, can be separated into sub-tasks. Sub-tasks should be chosen so that they regulate collaboration (Figure 13):

- There will be parts of the task that can be executed in parallel without impeding other parallel action (this often involves the spatial organisation of information, including actions such as grouping, connecting etc.)
- There may also be resources that are only appropriate for a single user to access. These singular tasks do not impede other user's parallel tasks.
- There will also be *key* subtasks that the collaborators must act on together, for example a decision point that affects the overall task. All

parallel subtasks should be suspended to emphasise the importance of the task.

Chapter 4

Study: School One

The previous chapter outlined a learner-centred design process for producing an application for the collaborative learning of the Extended Writing task. The design built upon key concepts such as internalisation, externalisation and collaboration (section 2.3.1), scaffolding (section 2.3.2), Distributed Cognition (section 2.3.3) and visuospatial representation (section 2.3.4). CCW was designed for digital tabletops, in order to exploit their affordances as a collaborative medium (section 2.5).

The final design (version 1.0), produced after three iterations, represents a potential answer to the research question *"How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?"* – However, it is only designed for single groups and does not help in answering the second research question *"How can a small group based collaborative learning task be scaled up to an 'in the wild' classroom multi-group deployment?"* It has also not yet been evaluated in an authentic learning context.

This study begins the process of answering this second question, by outlining an "in the wild study" in a classroom. Based on the literature investigated in chapter 2 that suggests there is a potential learning benefit from allowing collaboration in a usually non-collaborative learning setting, the study attempts to evaluate CCW as a "learning tool" through identifying and evaluating collaborative behaviours around CCW, in particular the designed-for collaborative elements of visuospatial representations and decision points. The study aims to address the research objectives:

- Adapt the collaborative learning design to the reality of the classroom and available technology – by utilising more commonplace technology (i.e. SMART tables) and adapting the design of CCW to the technology and environment (i.e. version 1.1).
- Examine the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment – by recording the progress of the study from multiple viewpoints and deriving key issues to be addressed in such a deployment.

Ultimately, however, the study aims to evaluate CCW in terms of collaborative behaviours (as opposed to improvements in writing, which would require a much larger study to ascertain), when situated in the classroom.

4.1 Study Purpose: Researcher Expectations

The intention of the study is to evaluate the collaborative writing application in a classroom environment. From the researchers' point of view, the design of the digital tabletop applications (both Digital Mysteries and Collocated Collaborative Writing) had been shown to work at the group level (i.e. Chapter 3). The challenge of the study was to scale the study up to using multiple tables in a classroom, and the intention was to run a single study in the classroom to accomplish this. To this end, the research team approached the deployment with certain expectations about who was responsible for various aspects of the study.

These responsibilities are summarised in Table 3 below:

	Researchers	Technology	Teachers	Students	School
Deployment – Who is responsible for assuring the room and schedule are correct and available?					X
Deployment – Who is responsible for the setup and management of tables per session?	X				
Planning – who is responsible for integrating the tables into the overall plan for the class?			X		
Planning – Who is responsible for the content of CCW?			X		
Orchestration – Who is responsible for differentiation and scaffolding?		X	X		
Orchestration - Who is responsible for progression of the task?			X		
Orchestration – Who is responsible for regulating behaviour in the classroom?			X		
Assessment – Who is responsible for Assessment?			X		

Table 3: Research Team Expectations

The reality of the study did not exactly match the expectations. It became apparent that the initial intention of evaluating CCW (1.1) in the classroom would not be fully possible, due to several factors, including:

- A mismatch between researchers' expectations and those of the other stakeholders.
- A naivety on the part of the researchers about the pragmatic realities of deployment in the classroom.
- A failure to acknowledge the necessity for fully engaging teachers in the study as well as the learners i.e. the teachers need to feel the technology is *for* them to utilise in *their* teaching agenda.
- Flaws in the study design, such as:
    - Having a big emphasis on the data collection being voluntary for learners at any point in the study. This lead to most group level audio being unavailable.
    - Following different groups each session, the intention being getting a classroom level view by tracking as many individuals as possible – however, this did not show aspects such as progress. The group should have been the unit of analysis rather than the individual. Similarly allowing group membership to be changed per session made it difficult to gain any information on group behaviour.

Instead, however, the study provided good insights into the nature of classroom deployments. The lessons learned from the deployment allowed for a more successful second deployment (i.e. Chapter 5) where more of the intentions of the study were fulfilled.

4.2 Implementing "In the Wild"

To maximise the veracity of the deployment, it must be conducted in as realistic scenario as possible. Ideally, this means situating the study in a classroom, integrating the task with existing lessons, fitting in with existing lesson topics and teachers agendas, facilitating the study in a realistic manner by having teachers facilitate the lessons rather than researchers. This is an "in the wild" aspect that has not been apparent in all such "in the wild" studies.

In order to realise these goals, an invitation was made to a local school to take part in a research study to test CCW 1.1 in the classroom. This resulted in the recruitment of four teachers, two in geography, one in history and one in English. The teachers initially took part in three 1-hour meetings, during which the functionality of CCW 1.1 was introduced, and a schedule for the deployment was agreed.

The deployment was to take place over six weeks, involving two classes of mid-level children in the subjects of History, Geography and English. A specific room was inspected before the start of the study, which allowed the technology to be deployed safely and in a way that data capture (i.e. video and audio) could be accommodated.

To integrate the study with teachers' current teaching topics, the teachers themselves created the content for the sessions based on their existing materials.

4.2.1 The School

The school underwent an Ofsted inspection in 2012 [90]. The report describes the school as:

> "*A larger than average secondary school. A higher than average proportion of students is known to be eligible for free school meals. Most students are White British and speak English as their first language. The proportion of students who are disabled or have special educational needs is average, although the proportion of those who have a statement of special educational needs or who are supported at School Action Plus is higher than average. The school is a specialist college in technology.*"

The report goes on to award the school "good" ratings in overall effectiveness, achievement of pupils, quality of teaching, behaviour and safety of pupils and leadership and management.

When approaching the school, initial contact was made between one researcher and the head teacher. The head teacher arranged a subsequent meeting at the university between a group of interested teachers and the university research team, consisting of the author and his supervisors. One of the research team had previous teaching experience in a similar school setting. During this

meeting, the concept and the technology were introduced, and an initial plan and schedule was agreed. The teachers were invited to produce content for their sessions, and had the opportunity to use the technology. A subsequent technology meeting was arranged, attended by some of the teachers at the school before the start of the study.

From working with the school, the impression given was of a culture largely focused on attainment and imparting knowledge (i.e. acquisition rather than participation [118]). There were frequent internal examinations and a prescriptive curriculum. The approach to teaching was influenced by this culture, with didactic lessons focused on the prescribed material. Teachers talked about "delivering the curriculum" and making sure that they "covered the curriculum for their subject", with little concern about transferable skills or cross curricular activities. Only one teacher (of the five) acted more autonomously, though was still concerned with prioritising the knowledge elements.

4.3 Study Design

The learner-centred design outlined in the previous chapter has produced a working prototype that has the functionality required to produce collaboratively written persuasive documents. This prototype is a potential answer to the research question "How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?" and as such needs to elicit the collaborative behaviours identified in the design:

- Learners should engage in collocated communication, i.e. discussion about the task.
- Learners should take advantage of visuospatial interaction with CCW 1.1 to:
    - Represent and communicate ideas.
    - Externalise Thinking.
    - Help decision-making.
    - Reduce cognitive load.

Participants were students of mixed ability, year 8 (aged 13-14), studying English, Geography and History, across two different classes. Five teachers were involved, two geography, two history and one English.

Classes	Students Per Class	Teachers	Subjects	Tables	Sessions
2	~30	5	3	Up to 7	Class A: 3 Class B: 2

4.3.1 Study Schedule

The study was conducted in several phases, and sessions were scheduled to fit in with existing school activities (such as training days and exams).

The study activities were conducted in the following order:

1. Pre-study group-work observation sessions (week 1)
    i. History – Class B
    ii. English – Class A
    iii. Geography – Class A
2. Practice session using tables (facilitated by Research Team) (week 1)
    i. Class B – Digital Mystery and Collaborative Writing
    ii. Class A - Digital Mystery and Collaborative Writing
3. Initial Pupil View Template activities (week 2)
    i. Class A:
        i. Group Work vs. Working Alone.
        ii. Solving a Difficult Problem
    ii. Class B:
        i. Group Work vs. Working Alone
        ii. Activity While Working in a Group
4. Main Tabletop Study (Part 1) (week 3 and 4)
    i. Class B: History –Queen Elizabeth I
    ii. Class A: English – Gothic Mystery
    iii. Class A: Geography – Jomo
5. Teacher Interviews (week 4)
6. Main Tabletop Studies (Part 2) (week 5)
    i. Class B: Geography - Jomo
    ii. Class A: History – Queen Elizabeth I
7. Post-Study Exercises (week 5)
    i. Class A: Bookmarks and Hands
    ii. Class B: Pupil View Template – Using the Tables

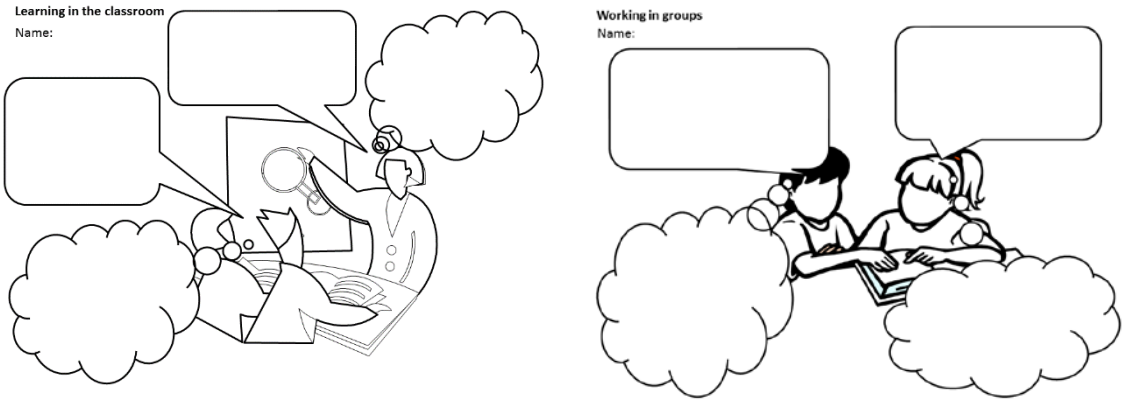
4.3.2 Pre-Study

Before deploying the writing application, several pre-study activities took place. Firstly, group-work lessons were observed and recorded on video in order to establish the kind of group based activities the students would be normally be involved in. It also gave insight into cultural aspects of the school. This involved the use of two cameras to record the lesson, and 1 – 3 researchers were present to take notes. The lessons were conducted by the same teachers that would be involved in the later writing study, and involved the same students.

4.3.3 Pupil View Templates

Part of answering the second research question *"How can a small group based collaborative learning task be scaled up to an 'in the wild' classroom multi-group deployment?"* requires some understanding of the thinking of the students involved in the study – the aim being to understand whether the use of the software might change students' disposition towards working collaboratively. Students were asked to complete a Pupil View Template (PVT) [133] exercise, to ascertain their disposition to various aspects of the study: Learning in the Classroom, Working in Groups, Working on a Problem and Working in Groups around a digital tabletop (Figure 14). PVTs allow students to differentiate their thoughts from what they would say aloud. This gives them more freedom to express what they actually think rather than what they think the teachers (or researchers) want to hear.

The PVT exercises were conducted after the students had an opportunity to use the technology in a practice session. An example of a completed PVT can be found in Appendix B: Example Pupil View Template.



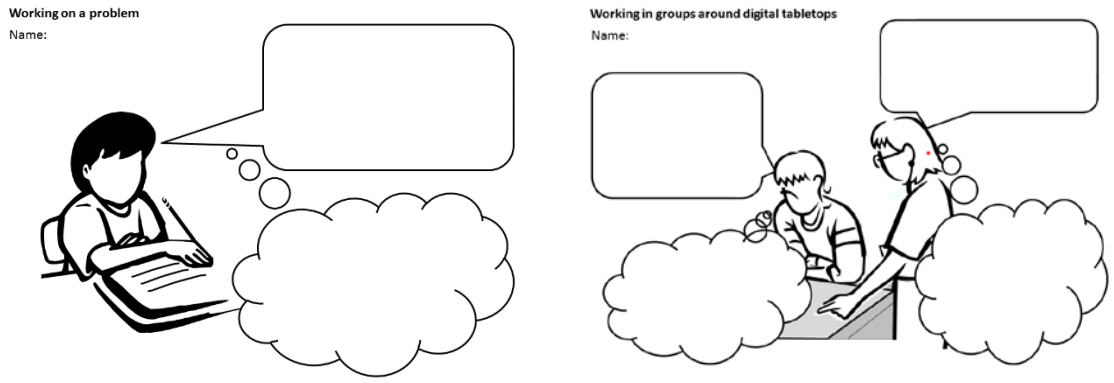


Figure 14: Pupil View Templates

4.3.4 Writing Study

To evaluate the design and examine if CCW (1.1) led to the collaborative behaviours that it was designed to elicit (i.e. around design elements such as visuospatial representation and decision points), it was deployed in a classroom setting. The 6-week study involved two classes with a capacity of ~30 students. The learners were 13-14 years old, working in groups of 2-4 on a collaborative Extended Writing task over 2-3 80-min sessions. To facilitate the study, seven SMART tables were deployed in a classroom in the school. Groups were not consistent throughout the study, with the teacher deciding on groupings on a per-lesson basis.

Each class completed the study across 2 or 3 subjects, the first class did History and Geography, while the second class also did History and Geography, as well as English. The subjects were chosen as they contain significant persuasive writing skill requirements in their respective curriculums. Before each collaborative writing session, the students first completed a Digital Mysteries exercise (Digital Mysteries are included in Appendix A: Digital Mysteries), using the same evidence data items as they would go on to use in the writing exercise.

In order to make sure the tasks were in line with the students' normal teaching as much as possible, materials (i.e. the Digital Mysteries) were authored by the teachers and were based on the existing curriculum. The teachers found this process difficult, with one teacher having their mystery completed by a member of the research team. The teachers also chose the groupings for the task and ran the sessions, which were scheduled in normal lesson time.

4.3.5 Post-Study

Following the writing sessions, several post study activities involving the students took place. Firstly, a series of semi-structured interviews were conducted with four groups of students and the teachers. The students also completed an exercise to ascertain their disposition to the study, which mirrored the earlier PVT task.

4.4 Data Capture

Sessions were filmed with two cameras focusing on the whole classroom and one on a single table. The group at the table was not consistent across the sessions; this was done to allow teachers across the subjects to choose their own groupings, and in the belief that a broad overview would provide a better basis for analysis than a single consistent group. Due to time and space limitations, it was not possible to record video and audio data from more than one table per session. It was intended that full video and audio recordings would be made at the table level, however most groups decided that they did not want to be audio recorded and so only video data was captured.

CCW 1.1 also logged user interactions, allowing replays of the process for each table. Two to four researchers were present (in the background) taking field observations and providing technical support when needed.

The study was required to fit in the real world scenarios of a classroom and school schedule. Attendance was not consistent across all sessions, so groupings were affected – some had a different number of participants between sessions. In addition, some groupings were changed at the teachers' discretion due to behaviour and attendance.

4.5 Results

4.5.1 Pre-study Observations

Before deployment, researchers observed group-work sessions within normal lessons. The purpose of this was to give researchers an understanding of the disposition of teachers and students towards group work, and what forms group based activities usually took during normal lessons. Three lessons involving group work were observed by the university research team, and the sessions were filmed

at a classroom level. The students and teachers were the same as would go on to take part in the deployed study. The following sections are based on observation notes and the videos from each session.

4.5.1.1 Pre-Study History Lesson

The first lesson observed was History, where students were studying the Spanish Armada as part of their work covering the Tudors. After a short individual form filling exercise, the class was organised into five groups of three to five students, which required rearrangement of the furniture in the classroom. For four of the five groups, three (rather than two) tables were placed together, making the horizontal surface a bit too large and leading to some group conversation being difficult.

The teacher asked the students to discuss the question "Why did the Spanish Armada fail?" in their groups. Students were given three options to focus on, "Spanish weaknesses", "English strengths" or "weather conditions". At the end of their short discussion, they had to write their answer on a mini-whiteboard, and the teacher asked them why they had chosen that option. The discussion process lasted around ten minutes.

There was a variety of behaviours exhibited during the group work - initially, some members of the class did not wish to participate and the teacher had to intervene in two groups' work (in particular one student refused to join in unless they had control of the whiteboard pen). Two groups discussed the question but largely agreed. One group just allowed the penholder to write an answer without discussion. The remaining groups discussed the question with some disagreement, but came to a compromise when answering. At the end of the task, when the teacher asked why groups had chosen their answer, the group that did not discuss the question were unable to reason about their answer without prompting, after which they recalled some good reasons for their answer (fire ships allowed English to chase the Spanish fleet).

Following the discussion session, the groups were presented with an essay on the same question, and a mark scheme (the mark scheme was also displayed on the wall of the class so students were very familiar with it). Groups were asked to discuss the essay and decide what mark it merited, 4, 5 or 6. This task lasted around twenty minutes. Engagement was slightly better for this task - only two

students (both from same group) did not read the essay (everyone else appeared to at least try to). In the discussion phase, one student did not contribute. In three other groups the students discussed the essay and agreed on the mark they would give. In two groups, students disagreed on the mark, which lead to better discussion as to the reasons why they would give a different mark, for example:

"I think it's a level 4 because each point is only mentioned in it's own paragraph"

"I think it's 5 as they have a lot of points"

"But they don't link them across the paragraphs"

At the end of the discussion phase, the teacher asked members of the group what other specific members of the group had said. In the groups that had disagreed, because of their richer discussion, the students were able to give good answers to the teacher about others' point of view.

Finally, the teacher asked the students to give feedback about the essay to the writer. Initially they would write an individual answer and then form a group answer by discussing individual answers. At this stage, most groups referred to the marking scheme "he should have looked at the mark scheme". The students criticised the punctuation and grammar, as it was poor in the essay.

During both group-work exercises, the teacher moved frequently around the tables and generally gave almost equal amount of attention to each. The time the teacher spent at each table was usually in the range of 10-20 seconds. The teacher frequently emphasised to the students that they should 'work as a group' and asked students what other group members thought, to make sure that they listened to each other.

4.5.1.2 Pre-Study Geography Lesson

The second lesson observed was Geography. Participants initially completed a short word-search and crossword task individually for five minutes. This settled the class and prepared them for the main part of the class. For the next five minutes, the researchers and project were introduced to the class. The goals of the lesson were explained by the teacher at the front of the classroom. The topic was the location of Kenya and the life of the people there. Students were asked to recall

knowledge and processes they had previously learnt from the subject. The processes included what tools they had used (e.g. using a key) and how they had planned to work in groups.

The students then worked in groups in a "quick draw" task that took around ten minutes, incorporating an initial 2-3 minute reading activity using prepared data sheets. Then a member of each group collected questions printed on paper data items from the teacher, taking them back to the group to answer together. Once completed the paper data item containing the answer was returned to the teacher. If the answer was correct, the group could pick up a new question. The teacher helped groups who encountered difficulties. There was an element of competition, as groups who finished quickest were acknowledged by the teacher.

Students seemed familiar with the task format and had strategies to complete the task. Most groups allocated separate roles; a runner, who got questions and handed answers back to the teacher, a reader, who read out the question to the group, and researchers, who found the information from the data sheets.

Successful (e.g. quickest, but not necessarily having the best learning outcome) groups were more flexible with their roles, with the runner and reader becoming researchers while a question was being answered. In less successful groups, the runner and reader would leave the answering task to the remaining members of the group. Another strategy employed by successful groups was to divide the data sheets among the researchers, so that they could look at information in parallel (although some questions obviously referred to a specific data sheet, e.g. the map). Less successful groups would read the same data sheet together.

The next card-based task again took around ten minutes and involved groups reading questions from cards placed on their tables and sorting them into those questions they knew the answer to, and those they did not. The idea was that the group would work collaboratively as different members would have different knowledge levels and/or areas.

The students also had a strategy for this task that involved roles, a reader, answerer and sorter. Some groups swapped between roles for each question (i.e. turn taking). Some groups split into sub groups of pairs, then combined the piles at

the end. One or two groups discussed the questions, but most dismissed any question they could not get straight away as “don’t know”.

In the final five minutes, students were asked individually to fill in a “bookmark” about what progress they thought they had made. The questions were: What have you learned? What are you more confident about? What can you explain to someone else? What did you find difficult? Once the groups had written answers, the teacher asked some students to read out selected answers.

Overall, the lesson included short group subtasks under severe time constrains within a competitive atmosphere. The teacher did move frequently among tables although more mostly to the tables near the front of the classroom.

4.5.1.3 Pre-Study English Lesson

In the third lesson, the students were studying English. The group work task lasted the bulk of the lesson, around forty-five minutes. The task involved construction of a poster from magazine and newspaper cuttings (cut and stuck by the students).

During the activity, the teacher constantly moved around the tables asking and answering questions and giving comments. The large tables and the students’ arrangement around the tables imposed pair work in many instances rather than group work. Students frequently moved around the classroom and talked to other group members, or moved to look at the work of other groups.

Movement of students around the classroom seemed to increase over the course of the lesson and many students preferred working while standing rather than sitting. After around thirty minutes, many students seemed to have lost interest and started to wander around or show off-task behaviours.

The groups showed varying levels of discussion during the task and took on various roles. Students in charge of cutting pieces from newspapers were often outside the group discussions. One student was working individually most of the time with most of the discussions occurring between the pair of students sitting opposite. Later in the lesson, more students seemed to be working individually. Some students stopped participating towards the end of the lesson.

4.5.2 Pre-Study Pupil View Template Exercises

4.5.2.1 Class A

Class A completed two PVT exercises before the main tabletop phase of the study. The first exercise was designed to ascertain their disposition to group work. The students had to complete speech and thought bubbles for a teacher and a pupil in a scenario where the teacher was offering a choice to the class, to work individually or in a group. The responses were categorised as for or against group work, or neutral (Table 4). This activity took place after the group work lessons observed in section 4.5.1:

	For Group Work	Neutral	Against Group Work
Pupil Talk	18	0	2
Pupil Thinking	13	6	9
Teacher Talk	3	14	3
Teacher Thinking	2	7	11

Table 4: Class A PVT: Group Work

As the table indicates, some students have a difference between what they say about group work and what they really think about it. The "Pupil Talk" bubbles were largely in favour of group work, with many students identifying potential benefits, such as:

"I would like to work in a group because we can share each other's ideas and I can get on better."

However, the internal thoughts of students revealed mixed attitudes. Common concerns were about issues such as fairness and working relationships, as well as more positive reflections, such as:

"I think this is great finally we are starting to get some ideas and good comments what we are learning about its great lets go and get started."

Students considered that teacher's "talk" on the subject would be largely neutral, without any particular positive or negative slant. The talk from teachers was assumed to be instructive and authoritative rather than opinionated.

However, when considering the thinking of the teacher, students considered that this would be largely negative towards group work, citing behavioural issues, lack of control and general risk of lower performance:

"The teacher thinks that they would learn better independently."

The second PVT focused on solving a difficult problem; the students had to imagine they were struggling to accomplish some task and what strategy they would use to progress (i.e. press on alone or ask for help). The students responded in line with whether they were confident to solve things on their own or they felt stuck and needed help (Table 5):

	Confident	Not Sure	Stuck
Pupil Talk	3	0	16
Pupil Thinking	0	16	3

Table 5: Class A PVT: Solving a difficult problem

Students considered that their talk would honestly reflect the difficulty of the problem rather than show their confidence with the task. Asking for help was considered cheating or at least a form of defeat. They were more concerned with how they would look to others than getting to the answer, as reflected in their impression of their thinking:

"This is really hard but I don't want to say anything in case someone laughs at me! So I am going to try."

"I think I know the answer but I'm not sure it's the right answer."

4.5.2.2 Class B

Class B also completed two PVT exercises before the tabletop study (and after the group work observations in section 4.5.1). Both these exercises focused on group work. The first was the same as with Class A; the students had to fill in speech and thought bubbles for both a pupil and the teacher when being given the choice to work in groups or individually. The same classification of comments was used; for or against group work, or neutral (Table 6):

	For Group Work	Neutral	Against Group Work
Pupil Talk	14	3	5
Pupil Thinking	13	1	7
Teacher Talk	9	11	1
Teacher Thinking	7	10	4

Table 6: Class B PVT: Group Work (Teacher and Pupils)

Again, students' impression of their talk was largely in favour of group work. They saw potential advantages in combining the work of multiple collaborators in producing a better piece of work:

"I would love to work as a group because if all our ideas are combined it will be a better piece of work than by yourself."

When it came to their impression of their thinking, this class was more positive than the previous one. Their concerns were largely social, rather than work orientated:

"I would work on my own better but I like my friends and don't want to upset them."

Students in this class thought that teacher's talk would be more positive towards group work, however examining the content of the bubbles reveals that this based on students' impression of the amount of work a teacher wants to do during the class. A teacher might say:

"Do you want me to do the work for you or you can work in groups or by yourself."

However, the thinking behind the instruction could be to do with minimising effort:

"I don't really want to do the work for them."

This concept of the students assuming the teacher will push for a less effortful choice was reflected in the teacher's impression of the student's choices, as can be seen in section 4.5.4. Both parties assume the other will try to minimise their own workload.

The second PVT exercise completed by Class B also focused on group work, this time the scenario was activity during a group work task. Students were asked to fill in speech bubbles for the speech and thoughts of two pupils engaged in a group-work activity together. Again, responses were categorised as For, Against or Neutral (Table 7).

	For Group Work	Neutral	Against Group Work
Pupil 1 Talk	16	1	4
Pupil 1 Thinking	3	3	15
Pupil 2 Talk	14	3	4
Pupil 2 Thinking	6	3	12

Table 7: Class B PVT: Group Work (Pupils)

As can be seen from the table, students considered talk and thinking on the subject to be largely opposite, with talk being positive and thinking being negative. The positive talk seems largely appeasing (to teachers):

"I loved this lesson I hope we get to do it again we have made a really good piece of work"

"I like working in a group then we can get better ideas I think we have done well and I enjoyed it."

While thinking was largely focussed on the social problems in group work, ownership of the work and overall fairness. In particular, students were concerned that credit would not be appropriately assigned in a group scenario:

"I know it went wrong"

"I wish we used my idea instead of her idea. She kept getting praise because she copied off me"

"She did no work, just left me to do it all while she went on about pointless things"

"He was rubbish I done all the work"

"That was awful I hate it so badly, I hate working with him he is annoying, I wish he would cooperate"

4.5.3 Writing Study

The writing sessions were filmed (single table and classroom) and the tables logged interaction data. Audio recording (single table) was also used, however students were given the option of switching off the audio recorder, consequently in most sessions the audio was only available at the classroom level.

Table video and audio were annotated, and researchers observed sessions and made observations. The tables also logged time-stamped interactions, showing how the learners used the software. Interaction logs were not recoverable in all instances due to technical failings of the tables. Groups were not consistent throughout the study, with the teacher deciding on groupings on a per-lesson basis. Therefore, the interaction log information was not fully indicative of group-level progress, but was used to get a higher-level picture of the class in general.

Before each writing session, students completed a Digital Mystery on the topic. The Digital Mystery allowed the students to reason about a specific question by manipulating, grouping and connecting "data slips". These data slips were then directly reused in the writing task as "evidence" (Figure 15).

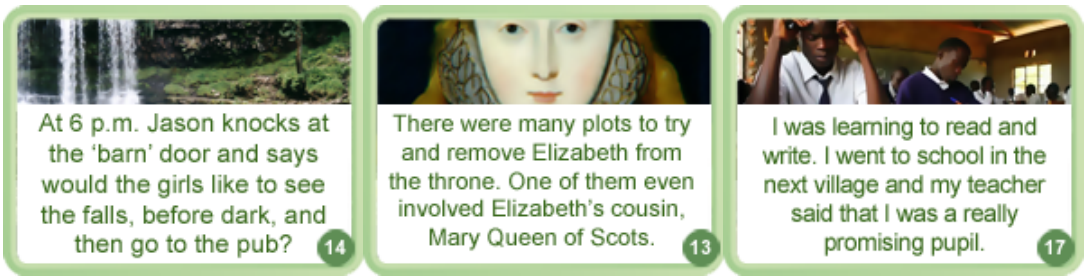


Figure 15: Example Digital Mystery "data slips" from English, History and Geography.

4.5.3.1 Classroom Observations – Class A

4.5.3.1.1 English – Gothic Mystery

The class had previously completed a Digital Mystery on "What is Richard Henderson about to say to Amina and Jenny?" – A mystery surrounding the circumstances of a tragic death. This mystery session was held in an adjacent computer lab, rather than the usual room, which lead to a difficult session where some groups struggled with the mystery. Again, five tables were used.

The session was observed by three researchers, and began with a whole class refection exercise covering their previous mysteries task. This involved using a single projection screen, with visualisations of each group's mysteries activity. The teacher attempted to pick out interesting decisions made by groups and invited the class to discuss them, and made suggestions on suitable ways the answers might have translated into paragraphs in the writing stage. This process took the first half of the lesson time (around forty minutes).

For the writing activity, students briefly reminded themselves of the evidence they had previously seen in the mystery session. As not all the students were engaged in this process, the teacher moved around the classroom from table to table in order to encourage and help the groups. After some time, the table selected for audio recording indicated that they did not want the recorder. Groups were operating at different speeds, with different levels of engagement. Some groups were going quickly, moving onto later stages using the discussion at the start of the lesson to inform their progress, while other groups were still in the initial stages and not progressing. As the teacher concentrated on single groups, other groups took the opportunity to disengage from the process.

Towards the end of the writing session, only one or two groups reached the text entry stage, and no groups finish completely before the end of the lesson. The writing activity lasted around thirty-five minutes.

4.5.3.1.2 Geography – Jomo

Class A had completed a Digital Mysteries session answering the question "Why is Jomo living on a rubbish tip (in Kenya)?". As with class B, the question was derived from the curriculum topic the class was covering regarding conditions in Kenya. This session was held in the usual room identified for the study.

The session was observed by two researchers. Unlike other writing sessions, the students did not start as a class with a reflection session on the central display, but rather at their group tables. The teacher had previously been given a printout of the reflection information (from the previous digital mystery), and the reflection materials were put on the display as a reference. Instead of using the display, the teacher addressed the class while they were at their tables and asked questions about the mystery they had solved, referring to his notes. This reflection stage lasted around 15 minutes.

After this, the teacher began moving from table-to-table asking groups how they were planning to complete the exercise. He was concerned with each group's approach to the whole task, rather than just the stage they were attempting. He asked why they had decided to make specific choices in their progress – e.g. why this paragraph and why this evidence. He moved between groups very frequently, using the table display as a prompt for which group to look at next (i.e. the ones that had made least progress).

At the connecting stage, the teacher handed out the connectives help sheet and stopped the class to explain what the connectives were for and how they would make the final document flow "like a story". After the explanation, he resumed moving from table to table as before. During this phase, when he came upon a particular problem he has observed was common across several groups, he would stop the class and spend a minute or two explaining the problem to everyone and how to solve it. He also did this to share particularly good points that groups had made, including at one point bringing the class over to look at one particular table.

During the writing stage, the teacher began distributing extra materials – photographs of the living conditions in Kenya. He would occasionally stop the class and talk for a minute or so about one of the photographs.

At the end of the lesson, for the final fifteen minutes the teacher conducted a class discussion about the lesson. He asked questions about the topic and about what decisions the groups had made within their writing task. He finished the class off with a homework question for the class – "if Jomo lives on the rubbish dump, where are all the other children from his village?" (The answer being in the same

or similar situation – leading the class to realise the work was about the general living conditions rather than an individual's circumstances).

4.5.3.1.3 History – Queen Elizabeth 1st

For Class A's third and final session, their usual history teacher was unavailable. The geography teacher from the previous session provided covered. As this was the same class (A), the replacement teacher was one the students were familiar with, and the session took place in the usual room. The class had previously completed the Digital Mystery asking the question "Should Queen Elizabeth 1st be allowed into heaven?".

There were three researchers present for the session. There was also a photographer present to take photographs for the study. The replacement teacher being unfamiliar with the content of the mystery seemed less confident about the session, often stating to the class that they would have to help him with some of the details about the material. The session began with a reflection session using the classroom projector display (while the students were seated in their groups). As the teacher had not been present during the previous Digital Mystery task, the reflection session involved a question and answer session around the content of the Mystery. After around 10 minutes, the teacher asked the class to start the writing task.

The teacher repeated the strategy of moving from table-to-table to help groups with their work, but being less familiar with the material there were fewer occasions where the teacher engaged the whole class with problems or examples of good work as he had in the previous session. He also spent less time with each group and moved around much more. The teacher only really engaged the class to remind them of which stage they should be on and what they needed to do for each stage.

Some groups finished the task quite early, while others only progressed with prompts from the teacher to move on a stage. All groups did eventually finish the task. At the end of the lesson, the teacher provided a summary of the task, and asked the class what they thought was the answer to the main question, ("Should Queen Elizabeth 1st be allowed into heaven?"). However, unlike the previous session where the teacher was familiar with the content, the questioning was superficial and did not go deeper into the material.

After the lesson had finished (and the students had left), the teacher had a short conversation with the researchers to reflect on the session and the whole study (as this was the final session). He admitted that the session was much harder for him as he did not know the material very well, and he felt he had less control over the overall flow of the lesson. He also made an interesting observation about how some students had engaged with the technology. He observed that some students who were less able when using pen and paper had performed much better on the digital table. He identified one student in particular, who normally would have gone to a special class for writing. The student had remained in the class (due to the teacher's judgement) and had engaged and performed well. The teacher also noted that some higher performing students did find the lessons slow and started to misbehave when they were "held back".

4.5.3.2 Classroom Observations – Class B

4.5.3.2.1 History – Queen Elizabeth 1st

Class B's first writing session took place in a History class and followed a Digital Mystery asking the question "Should Queen Elizabeth 1st be allowed into heaven?" The activity took up most of the 80-minute lesson. Due to absences, the class was divided into five groups instead of six. Table 5 (of 6) was unused. The class had previously completed a practice session using CCW 1.1 in a previous class.

The teacher began by asking the class to remind themselves of the evidence by reading the evidence data items. The class was initially unresponsive, and does not engage with the task. Some groups engage in deliberate disruptive behaviour – one group (table 6) repeatedly unplug the keyboard then complain that the table was not working, while another quit CCW 1.1 altogether and have to be restarted by a researcher. One of the groups (table 4) initially received help from a teaching assistant.

After the first reading stage, there was further disruption. The group using table 4 began eating and drinking, while those at table 2 were having a conversation.

At the connecting stage, some groups have completely lost interest. Table 6 were typing random phrases into the paragraphs, several groups skipped the instructions and "don't know" how to proceed (despite having no problems in the

earlier practice session). Only one group (table 1) progressed to the writing stage and no group completed the task.

At the end of the class, the teacher summarised the lesson: “You all seem to have struggled, what has made the task difficult? Were you sure about what you were doing?” The students’ responses are positive, i.e. they knew what the task was. When asked why they thought it had gone “badly”, one student suggests, “it would have been easier to use pen and paper, because then I would not have to make paragraphs". This was an example of a lack of engagement with the task, mistaking the focus of the exercise (learning to write paragraphs) with the medium (digital tables versus pen and paper).

4.5.3.2.2 Geography – Jomo

Again, the class had completed a digital mystery exercise, answering the question “Why is Jomo living on a rubbish tip (in Kenya)?”. The mystery called for the students to examine evidence specific to the main character (Jomo) and evidence general to the society of the area. The session took place in a larger central room than the usual lab. The room had several smaller side rooms, which held other lessons. This caused some disruption at the start and the end of the session while students from the other classes moved through the large central room to gain access.

This was the second time Class B had attempted a writing session on the tables, and the students were more attentive to the task. Three researchers were observing the lesson. Once again, the session begins with a whole class reflection exercise reviewing their previous mysteries task. As before, this involves visualisations of groups’ mysteries activity on a single projection screen. The teacher supplements this exercise with a paper-based question and answer sheet before the writing process begins. The reflection process and the paper-based exercise take up the first half of the lesson time (around forty minutes).

At the start of the writing session, the teacher commented to one of the researchers that she had been pleasantly surprised at how well the students had answered the paper-based exercise. The paper-based exercise also allowed for a smooth transition into the writing activity, as it reminded many students of the question and some possible answers.

The teacher circulated around the classroom and helped individual groups in turn. For the first reading stage, most groups progressed without incident, though some were waiting for a prompt from the teacher before progressing. The next stage (making paragraphs) also ran smoothly, although small technical issues with the table had to be corrected by a researcher. During the subsequent stage (inserting evidence), one student became disruptive and the teacher focused on their discipline. As the teacher was occupied, several groups stalled before progressing to the connecting stage. After the teacher had dealt with the disruption (the student was removed from the classroom), she told the class to proceed to the next stage, and resumed the table-by-table interactions. She also handed out help sheets for the connecting stage to assist students with connectives.

All groups managed to reach the final stage (Writing), with some groups finishing their answers. One of the groups who had previously seemed to struggle completed the task easily – when asked about it they stated that they had always found it "quite easy", but were not motivated to complete the task in the previous session. The topic had seemed more in line with their "everyday" work and not a novelty that "didn't count for anything".

4.5.3.3 Interaction Logs – Class A

Symbol	**Meaning**
	New Stage (Create Paragraphs, Insert Evidence, Connect Paragraphs, Writing)
	Create a Paragraph or an Evidence Slip
	Create a Note or Get Scaffolded Feedback (i.e. Stage Criteria not met)
	Insert Evidence Slip into Paragraph
	Connect Paragraph to Document
	Delete Item
	Move an Item
	End of Session

Table 8: School One Interaction Log Key

Interaction logs are presented as a *timeline visualisation*, the purpose of which is:

- to give an overall impression of the classes progress with the task as a whole, i.e. how far did the groups progress;

- approximately how long did they spend on each stage;
- how many paragraphs or connections were made etc.

The timeline visualisation also highlights the *decision points* encountered during the sessions, i.e. Ending a Stage, Creating a Paragraph or Connecting a paragraph. As the groups' members were not consistent across sessions, the timeline visualisation only gives a per session snapshot of activity and the above factors can't be tracked across sessions.

4.5.3.3.1 English – Gothic Mystery

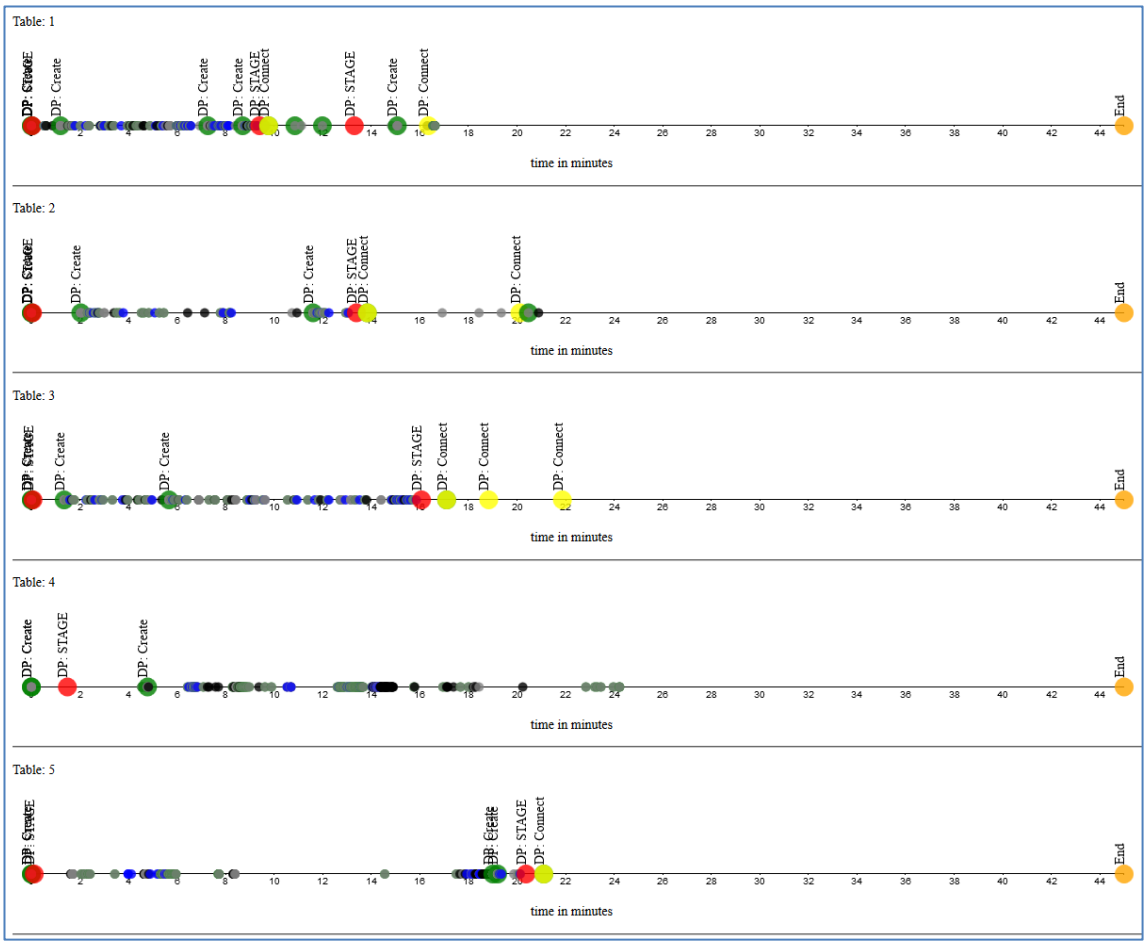


Figure 16: Interaction Logs - Class B – English Gothic Mystery

All interaction logs were recovered from the tables used in this session. The visualisation in Figure 16 shows the logs (the meaning of the symbols is shown in Table 8). Although no group completed all the stages, four groups were at least at the connection stage before the end of the lesson.

Some groups made good paragraph choices related to the topic, such as "the girls" or "suspicious", but most made generic paragraph titles, like "good points"

and “bad points” (or left the paragraph title blank). The connectives (where the relationship between subsequent paragraphs is made explicit) proved challenging, with some groups typing their whole paragraph into the connective text box.

4.5.3.3.2 Geography – Jomo

The Logs were recovered from the tables. Figure 17 shows a visualisation of the log, and Table 8 shows what the symbols mean. All groups completed the task, including writing a document. Two of the groups’ paragraph titles were relevant to the topic (e.g. “why is he going to Nairobi”), while the other two groups used generic titles like “good points” and “bad points”. Connectives were again a difficulty, though two groups did manage to make good choices. All groups used evidence within their plans, but there were many spelling and grammar mistakes (though that is not the focus of CCW).

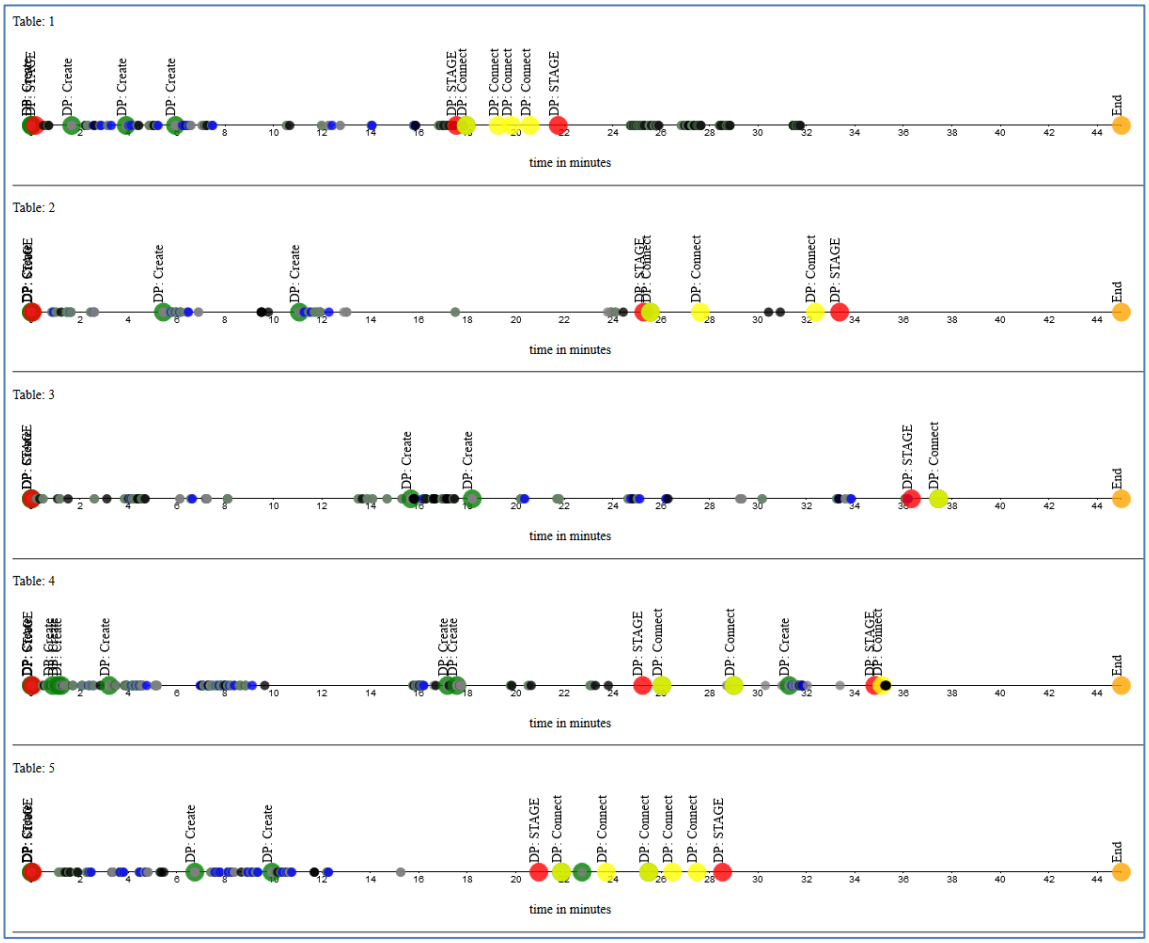


Figure 17: Interaction Log - Class A - Geography – Jomo

4.5.3.3.3 History – Queen Elizabeth 1st

All five logs were recovered from the tables. Figure 18 shows the interactions, the symbols are explained in Table 8.

Four groups completed the task, and wrote at least partial answers. Two groups chose relevant paragraph titles, such as "Family", while the other groups chose generic titles (or just repeated the question in the paragraph titles). The class again struggled with connectives; some connectives were used appropriately but mostly they were filled in with anything just to progress.

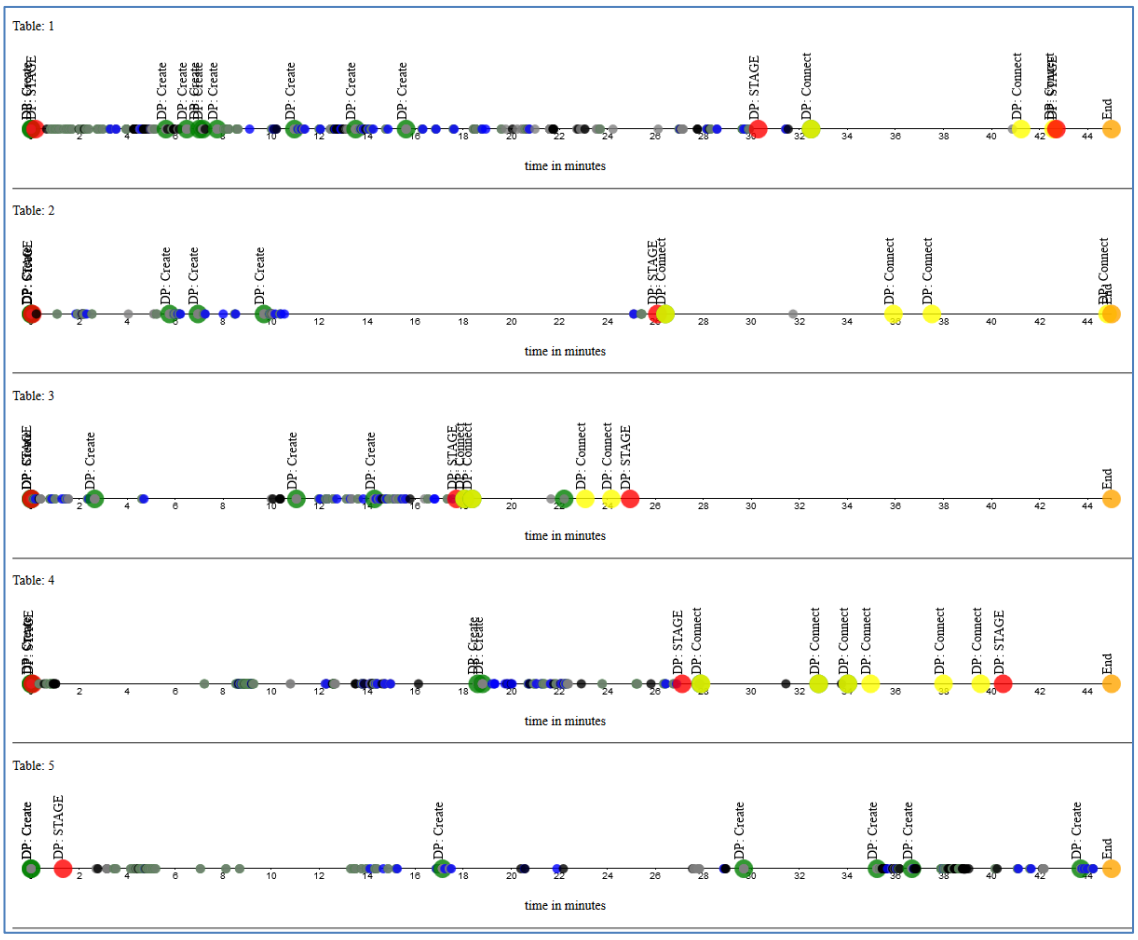


Figure 18: Interaction Log - Class A - Queen Elizabeth 1st

4.5.3.4 Interaction Logs – Class B

4.5.3.4.1 History – Elizabeth 1st

All five logs were recovered from the tables, the results are shown in the visualisation in Figure 19, the meaning of the symbols is shown in Table 8. They show that no group completed the writing task in this first instance – this was in

line with the observers notes that no groups produced a written output and only one group reached the final stage.

General activity on the tables was quite varied, two groups did very little (second and third in the figure) whilst others were quite active until the end of the class. Looking more closely at the activity shows that even active groups were not engaged in the task. For example, the fifth table in the log shows a high level of activity, but the group created paragraphs entitled “ha ha you smell” and “you lick hairy toes”. These were indicative of some of the common incorrect assumptions observed throughout the study. The assumption that the tables assist in regulating behaviour (from the viewpoint of the teachers – see section 4.5.4). The assumption that what happens on the table was highly visible to the teachers (from the viewpoint of the research team), and that all students would engage with the tables were incorrect.

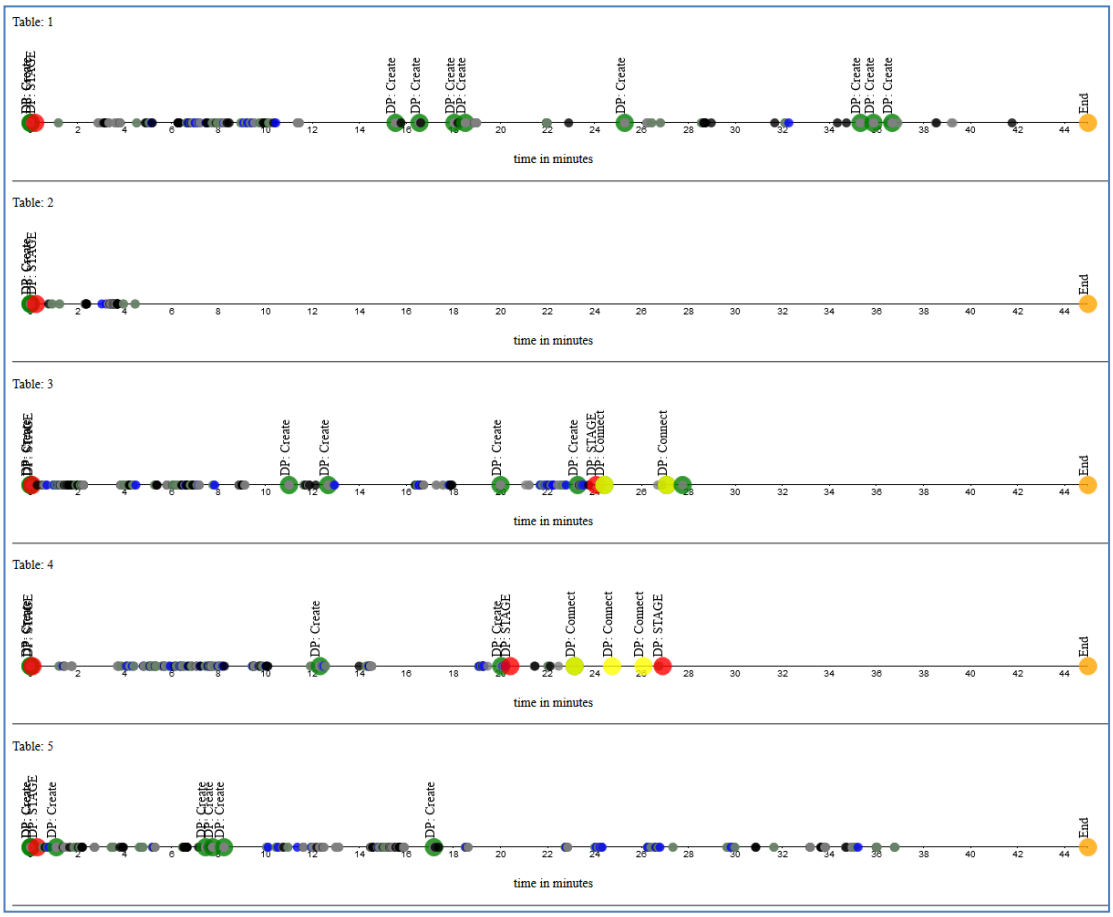


Figure 19: Interaction Logs - History - Elizabeth 1st

4.5.3.4.2 Geography – Jomo

Five logs were recovered from the tables. The logs are visualised in Figure 20 and the key to the meaning of symbols is in Table 8. On this second attempt at the writing task, most groups progressed onto the writing stage, with a couple of groups finishing with a final document.

All groups produced good titles for their paragraphs, relevant to the topic (such as "jobs", "family", and "Jomo's wants"). The connectives were more challenging, even with the help sheet handed out. Most groups used "correct" connective language, but not always in the right way, e.g. connecting disagreeing paragraphs with "because". Some groups completed the writing task and created paragraphs with good features of persuasive text.

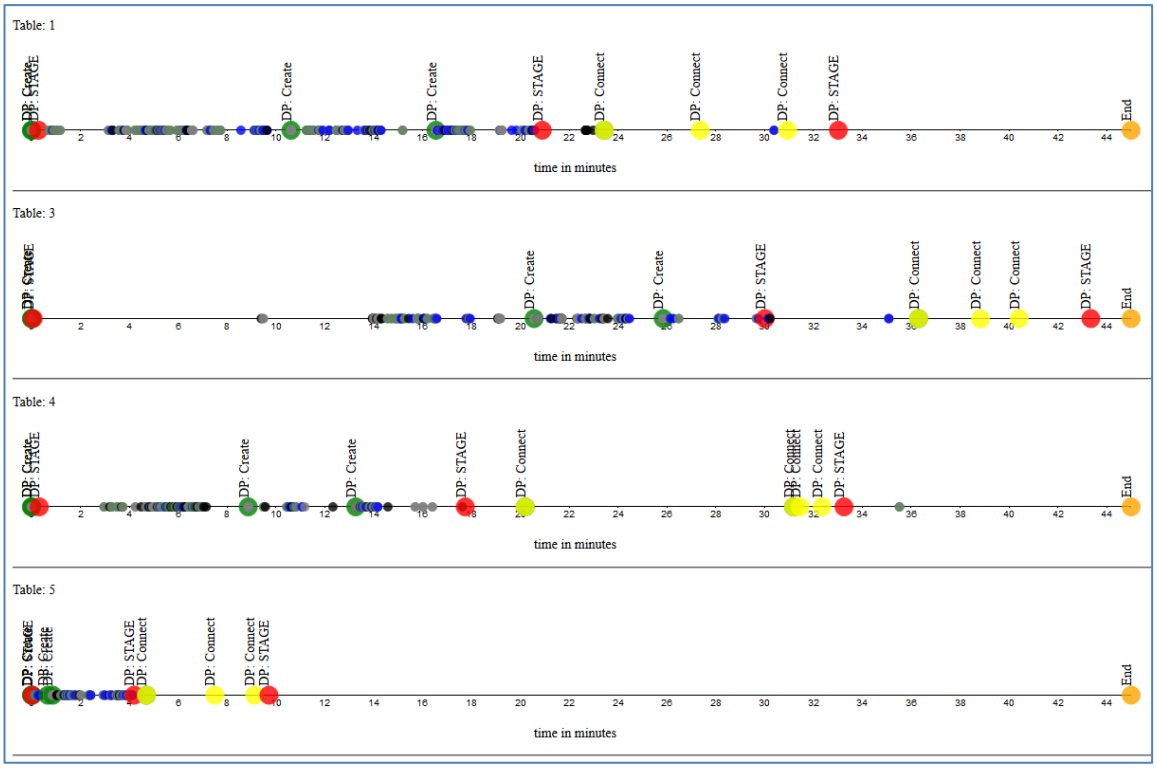


Figure 20: Interaction Logs - Class B Geography - Jomo

4.5.3.5 Table Observations – Class A

4.5.3.5.1 English – Gothic Mystery

One table had a dedicated video camera and table interactions were recorded and annotated. The group had four participants, and they decided that they did not want their audio recording, but were happy for video recording. The video audio

did allow for the general focus of the conversation to be observed, though not all utterances were recorded. A researcher also sat with the group during the session.

The group seemed more engaged with the task than in the previous session, though this may be partly due to the close attendance of the researcher. The group immediately moved on to the paragraph creation stage, as directed by the teacher. Their first action was to lay the initial paragraphs out spatially. They create their first paragraph "girls" after a brief discussion. At this point one student indicated to the researcher that they do not want to take part in the task. The rest of the group proceed without the student. The group begin discussing which evidence will go into the new group. During this discussion, the teacher asks the group why they are choosing certain data items, one student replied "it fits". After the teacher leaves, the group decide to delete the slip in question. The group repeated this strategy for further data items, selecting them and either including in the paragraphs or deleting, working in a paragraph-by-paragraph manner (even deleting data items they would later include in another paragraph). When they reached the next stage, one user decided to proceed and selects continue for the whole group.

The connection stage proved more challenging – the group were confused by the "connective" concept and ask for help. The teacher briefly explains the concept - "you have to think of a word or phrase that connects the paragraphs...". After the teacher leaves, the group discuss the connective, and eventually begin typing. However, they were actually typing the paragraph content into the connective box, showing that they have misunderstood either the concept or the interface. They repeat this error when connecting the subsequent paragraphs. The teacher provided a sheet of connector prompts to the group, but they do not alter their strategy. They eventually connect all the paragraphs in this way, and move onto the final stage just before the end of the lesson. (The third log in the interaction logs visualisation in Figure 16 represents the group.)

4.5.3.5.2 Geography – Jomo

As with previous sessions, one table had a dedicated video camera and table interactions were recorded. The group had four members.

They begin the task by creating, reading and deleting data items. This continued in the paragraph creation state. Two of the participants were disruptive

to begin with, making and deleting data items randomly and deleting text from paragraph titles. The group argued about deleting each other's work, but eventually calm down and started to engage with the task. They were however behind some other groups who have moved onto the next stage by now. The group finally managed to make two paragraphs and quickly started inserting evidence data items (with some good placement). By the time the teacher came to the group they have managed to make their paragraphs with evidence and arrange them spatially so that they can talk about their plans with the teacher. The teacher explained the next connective stage and hands out a help sheet.

The connective stage again seemed more challenging. One student typed some ideas into the connective box, but was not confident and deleted them. The group became distracted and started to talk about other subjects. The teacher returned and reminded the group about the help sheet. The group instead type more description of the paragraph instead of a connective. The teacher returned and helped with the next connection. After this, one student largely acted alone to complete the connection stage while the others watched.

In the final writing state, again the single user took control and wrote the content of the paragraphs, while the others watched. The answer was acceptable to CCW, and used some evidence, but was rushed at the end of the lesson. The group interaction log is the first one in Figure 17.

4.5.3.5.3 History – Queen Elizabeth 1st

As in the other sessions, one group was videoed and their interactions with each other and the table recorded. The group had four members.

Of all the sessions, this group started with the clearest role taking behaviour and overall strategy, but later became frustrated and more chaotic. One student took the lead and told the group what they should be doing at each stage. Initially, this meant organising the evidence and paragraphs spatially before inserting them. The group worked together to create evidence data items, read them aloud and "pile" them near to paragraphs (or delete them). They use the outline mode to get a quicker overview of the evidence.

The teacher addressed the class, reminding them of the task and the topic. At this point one student accidently deleted the start and conclusion paragraphs, but the group recreated them. Their strategy was using a lot of space, and the

rubbish bin was becoming a hazard, so the group move it as far off the screen as possible. The teacher came to the group and suggests a specific paragraph – strong queen, and the group work together to find evidence for that. They then discuss the next paragraph, and decide on "What she did bad". Before they can move onto the connective stage, CCW tells them than one paragraph has too few evidence points. The group drop a random piece of evidence in to continue. The group were becoming frustrated.

The teacher explains to the class the connective stage, but the group have already started to connect paragraphs together. The group were not taking much care over this process and make some errors. They were also typing in jokes instead of connectives (but deleting them and putting a correct connective in before confirming). The group tried to finish before they have connected all the paragraphs, but CCW informs them of their error (and the teacher explained what they need to do to proceed).

In the writing stage, one student dictated while another typed, leaving the other students just watching. The answer was typed all in the first paragraph, ignoring the structure. The groups' interaction log is the first in Figure 18.

4.5.3.6 Table Observations - Class B

4.5.3.6.1 History – Elizabeth 1st

One group of four was video and audio recorded for their session. The group begin by receiving direct instructions from the teacher to read the instructions for the first stage. After some playing around with the interface (making and deleting data items) the group begin reading through the evidence.

Once the teacher left the group, they begin playing around again (making and deleting data items), one student (user 3) asks them to stop deleting data items: *"let us read it then you spoon!".* He was becoming frustrated and eventually gave up.

The group then begin selling and swapping sweets rather than attend to the task. User 1 complains about this direct to camera: *"can you get these people told off please?".* The teacher intervened: *"you are in trouble (for eating sweets)",* he told the group that they should be filling in the paragraphs (with data items) and leaves the group. Eventually, one student pretended to fall asleep (user 3). The teacher

noticed this and warned the group. The student then complains that he was uncomfortable.

The group continue to chat and trade sweets, until the teacher returns: *"what have you managed? Can you put something in this (good) paragraph?".* One of the students (user 3) found a slip to put in the paragraph. However, once the teacher has left, user 1 deleted the slip from the paragraph.

The teacher returned a few minutes later and helped the group finish the paragraph by making suggestions: *"what about this one?"* and user 3 then reads out the slip then puts it in paragraph. After the teacher leaves again, the group continue chatting and user 3 lies down across the table. Towards the end of the session, the teacher asked the entire class: "what paragraphs the groups have made?" User 1 from the group responded with the solitary "Good Points" paragraph that the group (with teacher's help) have constructed.

4.5.3.6.2 Geography – Jomo

Again, one table had a dedicated video camera to record table interactions. The group initially consisted of three participants.

From the beginning of the session, one of the group members was not engaged with the task. The remaining two members worked on the task together without complaint. Before starting the task, the teacher handed out a help sheet for the connective stage and all groups move straight on to the create paragraphs stage. The pair begins by spacing their initial paragraphs (provided by CCW) out together (i.e. simultaneously). The teacher noticed the third member not participating and gave them a warning. The other members continued by examining evidence, and decided together to reject (by deletion) the first few data items they create. By now, the third member was being disruptive to the class and eventually the teacher had to send them out of the room. The remaining members continued working on the initial paragraphs.

When working on individual paragraphs, the pair moved one paragraph into focus in the centre of the screen (having moved the other paragraphs off to the side). They decide what evidence was required, then moved onto the next paragraph. They use this strategy to complete all their paragraphs. Their verbal communication was minimal, instead they used the interface to propose evidence to be included (by moving it into the middle) then responded with a simple yes or

no. There is little debate; evidence was considered only in this simple manner. Towards the end of the paragraph stage, one participant decided they needed a further paragraph (they had been working only on the initial two), and went on to create it. The teacher visited the group soon after this to ask how the group was doing. The pair discussed their decisions with the teacher, received some prompts on how to improve their work, and provided with more background on the topic. The pair went on to add more evidence to their paragraphs based on their discussion with the teacher.

Near the end of the lesson, the teacher prompts the class to move onto the next connective stage if they have not already. The pair attempt to move on, but the table informs them they have too few paragraphs to proceed (only three). They quickly create another paragraph and begin filling it with evidence. They move on from this stage just before the lesson finishes, making a single paragraph connection in the final moments. Their interaction log is the third in the visualisation Figure 20.

4.5.4 Post-Study Exercises

In order to ascertain the disposition of the students towards the digital table based study, the students were again asked to do a PVT exercise focused on the table usage in group work.

4.5.4.1 Class A

As a post-study exercise, the teacher preferred to use their own material rather than the provided table focused PVT. This entailed two similar exercises, the first, "hands" asked the students to label the five fingers and palm of a hand with specific statements:

- little finger = what can be improved
- Other fingers = skills learned
- Thumb = what you enjoyed
- Palm = what the tasks were (i.e. what did we have to do?)

The second exercise was "bookmarks", students were asked to fill in a bookmark style list with statements about:

- I feel more confident about...
- I now understand...

- I can explain to someone else that...
- The most difficult thing about today's lesson was...

In the "hands" exercise, there was a unanimous response to the first topic, "what could be improved". All participants' responses (17) indicated that the sensitivity of the digital tables was an issue, while the remaining participants failed to respond. In the remaining topics, opinions were more diverse:

Skills Learned	
Teamwork	15
Using Tables	8
Thinking	9
Task Specific	11
Time Management	2

Table 9: Skills Learned

Table 9 combines all the responses from skills learned (up to three per participant) and indicates that around a third of the responses show that the participants' felt that their teamwork skills had improved – though no participants provide a specific example. When it comes to the task itself, most (20) participants indicated that they had acquired skills (Task Specific and Thinking), however only half of these (9) indicated that the skills were conceptual, i.e. How to think about writing, rather than mechanical task specific skills such as "joining paragraphs". Somewhat surprisingly, some participants indicated that their skills with the tables had improved, despite the overall negative feedback from the "what could be improved section". A couple of participants also stated that their time management skills had improved during the study.

What You Enjoyed	
Technology	6
Teamwork	2
Nothing	11

Table 10: Enjoyment

Table 10 shows that the overall perception of enjoyment of the study was negative, with over half the responses being "Nothing". Slightly surprisingly, however, using the technology was the majority response, while teamwork was acknowledged also.

What We Had to Do	
Mechanical	16
Conceptual	2

Table 11: What We Had To Do

Finally, Table 11 shows that the participants' concept of the task was largely mechanical, i.e. the movement of the elements around the table, while only a couple of the participants extrapolated this into the concepts of writing.

In the "bookmarks" exercise, participants provided comments as follows:

What are you Confident about?	
Teamwork	6
Technology	7
Task	1
Individual Skills	3

Table 12: Confidence

Table 12 agrees with Table 9 in that it shows that around a third of the participants felt that they had become more confident in their teamwork-based skills, such as communication etc. Again surprisingly, they also indicated a gain in confidence using the technology despite their negative attitude towards it generally. Only one participant said that they were more confident about the task specifically, while three stated that they had gained confidence individual skills such as reading.

Increased Understanding	
Mechanics	3
Topic	6
Technology	8

Table 13: Increased Understanding

Table 13 shows that the participants' perception of their understanding the technology increased, though some of the comments were in line with previously expresses negative opinions. Around a third of participants indicated that their understanding of specific topics in the study had increased, while three participants stated that they understood the mechanical process of the task.

What Can I Explain To Others	
Mechanics	3
Topic	7
Concept	2
Technology	5

Table 14: What Can I Explain To Others?

In Table 14, participants indicated what they felt they could explain to a novice about the activity. Around a third thought that they could explain the topics covered during the study to others, while a similar number thought they could explain using the technology (including their negative experiences). With regard to the process of writing, again around a third indicated they could explain the

activity, but of this group, only two participants talked about the concepts rather than the mechanical processes involved.

What We Found Difficult	
Technology	5
Mechanics	6
Topic	1
Concepts	2
Time	1

Table 15: What we found difficult?

Table 15 indicates that there was a variety of aspects that participants found difficult. Technology difficulties again focused on the sensitivities of the tables. Around a third indicated that the mechanical processes involved in the task caused difficulty. There was also some indication that the topic, time management and overall concepts caused problems.

4.5.4.2 Class B

Class B completed the provided PVT, which focused on group work specifically using the tables. Students had to fill in speech and thought bubbles for a teacher and a pupil about using the digital tables for group work. The responses were categorised as being positive, negative or neutral about using the digital tabletops (Table 16):

	Positive	Neutral	Negative
Teacher Talk	9	8	2
Teacher Think	8	3	8
Pupil Talk	10	3	6
Pupil Thinking	1	0	18

Table 16: Class B PVT: Digital Tables

Overall participants indicated that they thought teachers would be positive (or at least neutral) in their talk, but from a perspective of making their work easier:

"I love it, it's great, not as much lesson planning. Look at these tables aren't they good? They are better than using a pen and paper."

When it came to the teachers thinking, opinion was much more even between positive and negative statements, for positive aspects, again learners thought that teachers would base their opinion on the difficulties that they would face:

"Much easier to teach using these boards, just have to check once in a while if they need help."

"Much better tell them whether to go on the software and they do what they are told."

"Wow these tables are really good they are way easier to use in lessons."

When thinking of their talk, students were largely positive:

"We don't need help, we can work really well on the SMART tables, they are really easy to use and fun to work with people."

However their impression of their thinking was more negative:

"Im getting really bored, i work better in a normal classroom where i can think and work better."

"If we did something different every time it would be a lot better."

A lot of the negative thinking was based on sensitivity issues on the tables:

"If their technology was better I would enjoy them more."

"I'd rather just write on paper than do this because it's confusing and it doesn't work properly."

While some students were negative about group work in general:

"We should get to work by yourself."

"What happens if we don't get along together and the person won't let anyone do anything."

Students also thought that tables were of more benefit to the teachers than they were to the students:

"Sometimes when I touch it is good but what would a teacher do because the tabletop tells you everything and the teacher is left doing nothing."

4.5.5 Teacher Interviews

Towards the end of the study, a semi-structured group interview was conducted with the researchers and most of the teachers involved in the study. The interview was recorded and transcribed.

The first item discussed was the PVT exercises. Both the researchers and the teachers were concerned that the PVT were taking too long to complete (over half the lesson), with one teacher stating that they did not know what they were for. The researchers re-explained that the purpose was to ascertain the disposition of the students towards various aspects of the sessions. (This teacher later replaced the final PVT exercise with her own task, see section 4.5.4.1).

The researchers then asked about any positive aspects to the tabletop studies. Several teachers were "surprised" that some students who would normally not be engaged with "pen and paper" exercises were more involved in the lessons. However, the converse was also true – students who were comfortable with "pen and paper" either struggled or were bored. The teachers also commented that some high performing students also picked up the table tasks easily.

A researcher posed the follow-up question "*So is it interesting that some students are highly motivated but not high achieving? Is there a disconnect there? Could the tables be beneficial for those students?"* The teachers were initially confused about the concept of a motivated student not being high achieving. They said that they did not feel they had a way to know if the students were achieving on the tables in order to make the comparison. On a class level, the teachers did not think there was a change in the level of engagement, and that the students who did become more engaged were predictable (despite the same teacher saying the opposite earlier). In fact, two teachers stated that the engagement of individuals who usually struggled was lower than they expected, again the opposite of what they stated earlier in the interview. The main issue seemed to be the sensitivity of the table technology, echoing what the students fed back in their PVTs. One teacher indicated that quite a few students had the attitude that "if they can't do something straight away they would give up and not participate".

When discussing more generally how the groups worked, one teacher pointed out that some students did not work well in groups, giving the example of one student who grew frustrated that the others in his group were not going along

with his choices and felt ignored. The student was annoyed he could not make changes to part of the document that had earlier been created. (This was actually possible in the software, the teacher was attributing a disruption in the group – the others not letting him make changes, to a flaw in the technology - the teacher suggested that this would not be a problem with pen and paper). A researcher pointed out that having a shared workspace required co-operation, but did not explicitly prevent disruption and exclusion.

Picking up the theme of disruption, teachers had several examples of how students could be disruptive on the tables, for example deleting all their work. The teachers indicated that this was difficult to prevent because they could not see what was happening on the tables. This was interesting as one of the goals of the software was *visibility*. One teacher suggested again that this would not be a problem with pen and paper.

When talking about the study as a whole, the teachers then without prompting began again talking about positive aspects of the study. They reiterated that some students who normally struggle were more engaged (agreeing with their earlier sentiments but disagreeing with later statements). One teacher was impressed with the amount of retention of information between lessons, which was not "usual". The other teachers agreed with the statement, with further examples. The teachers acknowledge that some of the behavioural issues could be to do with the novelty of the technology, an unfamiliar setting (not their usual classroom) and unfortunate scheduling – "I usually avoid collaborative work on that lesson. They don't work well after PE..." One teacher however did not notice an effect from the new environment. All the teachers agreed however, that having the sessions "squeezed" into a single half term (six weeks) made the study difficult for all parties, and in particular led to "boredom" in some students. They also noted that although the same students attend the different classes, they do not necessarily understand that the skills learned in one lesson were transferable to another. The students think that writing a geography document is fundamentally different from a history document, despite their being the common "persuasive document" theme. One teacher also pointed out that the pressure of upcoming exams was a big factor for some students who were getting worried that their results might be affected negatively.

The discussion then moved on to the priority that the school puts on high level thinking skills in addition to knowledge requirements. The school had some schemes in place, but it was clear that the teachers themselves were sceptical about the concept, in particular with regard to assessment and differentiation in the class. This was referred back to the lack of transferable skills mentioned earlier, but the teachers were adamant that they had explicitly tried to teach skills in a transferable context, but that it was not a popular approach with the students. One teacher admitted however that "*We don't do cross-curricula stuff. I don't have a clue what year 8 English are doing now*".

The interview then focussed on how things could be improved. The teachers were very keen on extra orchestration technologies, such as being able to freeze the tables, or more indicators about where groups were in the task. The discussion then again covered some problems with the technology and the student behaviour – such as deleting items, switching the machine off, feigning errors to avoid working and "just filling in stuff to get to the next stage". Another significant improvement suggested was to restrict the time for the task so that it did not become boring or arduous. This led to talk about differentiation to allow lower performing groups to complete the task in a shorter time, such as fewer data items or lower requirements for those groups. Teachers also pointed out that the structure of the task allowed some students to "duck out", especially in the final writing stage. This was partially attributed to the students not having anything individual to produce for assessment; a group project produces a group result. One teacher suggested separating the final writing off as a separate task (maybe as homework), maybe with each member writing a paragraph. Another suggestion was to make the writing a whole class exercise.

The discussion moved on to how the teachers could get more from the study. The main issue was the teachers feeling they could not assess the work done on the tables, or judge progression. In particular, how can the task be integrated into things like Ofsted reports and curriculum requirements. The teachers also re-iterated that the tight schedule did not allow for marking and feedback to inform future sessions, e.g. designing subsequent sessions and content based on the previous lesson's outcomes. The teachers also suggested ways in which a shorter task could be used in conjunction with other tasks in the lesson. Integrating the

technology into "real" classrooms also came up as an issue, in particular when not in use for this particular task. The teachers suggested other tasks that could be on the tables, such as collaborative searching exercises, multimedia etc.

The final topic of discussion was about the teachers' personal experience of running the sessions. Only one teacher said they enjoyed the sessions. The other teachers found it hard to manage the class, taking all their focus and losing site of the pedagogical objectives, with one admitting, "*I don't know what the objective is for the task*". The same teacher also admitted that they had not planned their sessions (not even adapting a "normal" plan). The other teachers admitted that though they did make plans, the lessons did not go as expected. One teacher summed it up – "*I know we got some training and stuff, but I sort of felt like I didn't know what I was doing so it was difficult to tell the kids what to do*". When asked if the task might be better suited to older children, one teacher replied, "*I think if you did this with year 11 or 12 you would have the same problems, maybe not to the same extent - In education now, they are not used to properly think for themselves. I do not think they are used to proper collaborative work. Because the teacher at the end of the lesson has to know that the students know those pieces of information. So we would never let them get to the stage where they were working collaboratively and haven't got the proper answer.*"

4.6 Discussion

4.6.1 Expectation

The study provided significant insights into the expectations of the deployment of the key participants – the Researchers, the Teachers, the School and the Students. All parties had incorrect assumptions about how the study would be managed, how the technology would work and even on the purpose of the digital tabletop tasks. This greater understanding of the point-of-view of the key parties raises several key issues and allows for improvements in future study design. This revolves around the perceived *responsibility* for the key aspects of the study.

4.6.1.1 Researchers

The researchers' perceptions of responsibility for the various aspects of the task are outlined in Table 3.

Section 4.7.1 details the practical realities of this challenge. Initially the researchers made the incorrect assumption that a dedicated space would be available for the study, hence setting up the technology once rather than every session – the researchers assumed that the school would be responsible for this aspect of the deployment. However, the reality was that the school could not guarantee specific room allocations or times far enough in advance. In addition to these practical challenges, there were several expectations and assumptions about how the study would proceed that proved inaccurate. The first issue arising from the study was therefore the planning and implementation of the actual deployment, with a necessity to establish a room allocation and schedule with the partner school.

Issue 1: Planning and Implementation of deployment

The researchers assumed that the design of the software was highly visible to teachers, and hence teachers would be able to assess the progress of students during the sessions. Following discussion with the teachers, this proved to be inaccurate – teachers felt that they did not know what was going on at the tables, and did not recognise disruptive behaviour as opposed to productive behaviour. This was partially due to the design of the software, and the experience of the teachers using the tables – only one teacher facilitated multiple writing sessions for example. This raises two more issues, the design of the software and allowing individual teachers to gain experience.

Issue 2: Improved software design

Issue 3: Teachers gaining experience in using the technology

The researchers were also in the position of understanding the limitations of the technology – something that was taken for granted. With regard to the teachers' experiences in the study, this should have been communicated much better. On the other hand, only one of the researchers had experience when it came to classroom management, and they were not available for every session. The

research team could have drawn more on the expertise of the teachers in this regard.

4.6.1.2 Teachers

	Researchers	Technology	Teachers	Students	School
Deployment – Who is responsible for assuring the room and schedule are correct and available?	X				
Deployment – Who is responsible for the setup and management of tables per session?	X				
Planning – who is responsible for integrating the tables into the overall plan for the class?	X				
Planning – Who is responsible for the content of CCW?			X		
Orchestration – Who is responsible for differentiation and scaffolding?		X			
Orchestration - Who is responsible for progression of the task?		X			
Orchestration – Who is responsible for regulating behaviour in the classroom?		X			
Assessment – Who is responsible for Assessment of work?		X			

Table 17 : Teachers' perception of responsibility

The teachers are the domain experts in lesson planning and classroom management. They are less experienced in the technological elements of the study, hence the discord between their perceived responsibilities and those of the researchers. The teacher interviews above (Section 4.5.5) were subjected to a thematic analysis, and formed underpinning analysis of the collaborative work presented in Kharrufa et al. [58]. This work focussed on the design challenges for learning applications in the classroom, but touches on the disparity between

teacher's and researchers expectations of the study. Taking this further, additional data was sought to make explicit the teachers expectations. To this end, the teachers were asked at the end of the study to give feedback on their perception of who was responsible for the different elements of the study (example in *Appendix C: Example Teacher Expectation Table* summarised in Table 17). It is apparent from comparing this with the researchers' expectations (Table 3) that the teachers felt that much more of the responsibilities lay with the technology and the researchers.

In particular, the limitations of the technology had a large impact on the perceived responsibilities during the study – teachers assumed that the technology could do far more than it could, and deferred responsibility to the technology that it was not capable of fulfilling. This leads to the next issue (which is linked to the experience of the teachers using the technology):

Issue 4: Understanding the limitations of the technology

This alienation from the technology, and the general deferment of responsibilities had a deeper underlying effect. The teachers did not take ownership of the technology, they did not see it as a tool they could use to realise their own agendas in the classroom but rather as a replacement for some of their tasks. From the teacher interview in section 4.5.4, the teachers showed that they had differing constructs about teaching from those that the technology was trying to activate (i.e. higher order thing skills, collaborative learning etc.) Ideally, if the technology were to be embraced fully, it would be heavily integrated into lesson plans, teachers would suggest and make improvements to its usage and make strong links between the table sessions and other areas of their teaching. This did not happen in the study, and was probably the largest failing, and perhaps the hardest obstacle to overcome.

Issue 5: Give Teachers ownership of the technology

4.6.1.3 Students

From the PVT exercises and teacher feedback, the students' main issue with the study was the reliability of the technology. Some improvements to the design of the software (i.e. issue 2) are also required.

Issue 6: Reliable Technology

Aside from this, they had a different perception of the responsibilities in the study from the teachers – from observing the sessions, the PVT exercises and informal conversations with students, their idea of responsibilities are summarised as:

	Researchers	Technology	Teachers	Students	School
Deployment – Who is responsible for assuring the room and schedule are correct and available?	X				
Deployment – Who is responsible for the setup and management of tables per session?	X				
Planning – who is responsible for integrating the tables into the overall plan for the class?			X		
Planning – Who is responsible for the content of CCW?			X		
Orchestration – Who is responsible for differentiation and scaffolding?			X		
Orchestration - Who is responsible for progression of the task?			X		
Orchestration – Who is responsible for regulating behaviour in the classroom?			X		
Assessment – Who is responsible for Assessment of work?			X		

Table 18 : Students' Perceived Responsibility

The fact that the teachers deferred some responsibilities to the technology, along with the fact that the teachers were clearly not experts in the technology and the fact that the students knew they would not be formally assessed for the work led to an atmosphere where students felt that no-one was in control and the work did not matter. This affected student behaviour. If the work had been more integrated with their overall learning (i.e. issue 5 above) then there would perhaps have been some purpose in their work.

Issue 7: Give students' work purpose

4.7 Reflection

The initial purpose of the study was to evaluate the collocated collaborative writing application in an "in the wild", class-wide environment. Previous digital tabletop studies had concentrated on single groups, or were held in controlled environments, facilitated by researchers. As the study progressed however, it became clear that the scope needed to be widened. The study provided insights into the larger issue of integrating technology into a specific learning context. The realities of a classroom deployment in a working school were significant, but the study also allowed for a greater understanding of the *expectations* of the key parties involved – the researchers, the teachers, the school and the students – and how to use this knowledge to inform subsequent study designs.

4.7.1 Evaluating the Collocated Writing Application

There are two main reasons why a full analysis of the writing application is not possible from this study.

Firstly, the data collection strategy – focussing on different groups each session rather than following a single group – made it difficult to ascertain progress or changes in attitude from the learners towards CCW (version 1.1). This was done to allow teachers across the subjects to choose their own groupings, and also in the belief that a broad overview would provide a better basis for analysis

than a single consistent group. The reality was that any evaluation required multiple sessions to be useful, so this data collection strategy was flawed.

Secondly, the larger issues of the classroom deployment, regarding mismatched expectations etc. dominated the study, leaving CCW evaluation as a secondary concern.

Despite this, there were certain observations that could be made about the application. One of the main purposes of the design is to "force" collaboration through decision points. The risk of this is that it breaks individual learners flow or concentration. In this study, there is not enough data to evaluate whether the benefit of decision points outweighs this potential risk, however there were a few isolated incidents where individual students wanted to work alone on "their part", resulting in disengagement when a decision point occurred. This is something to watch out for in future studies.

4.7.2 Realities of a Classroom Deployment

The "in the wild setting" of the study means deployment in an authentic environment of an ordinary classroom in a school. There are many practical issues with this scenario, some proved predictable, while some required adaptation of the study plans, occasionally at very short notice. This section outlines some of those issues, the effects on the deployment and the solutions that were developed.

4.7.2.1 Changing Tables

The first major issue encountered was accessing enough tables to allow a classroom study. The study required maximum group sizes of four, and class sizes were twenty-eight (assuming no absentees). This meant seven tables were required.

The application was designed on a pen-based table based on a Promethean whiteboard orientated horizontally. This is a bespoke piece of equipment created in the lab, and as such only three existed. They also happen to be large and heavy, making transport and deployment an issue. To resolve this, a replacement commercial technology was required. The lab already had several SMART tables, and several other SMART tables were available from other sources in the university. SMART tables are smaller, lighter and transportable; so seemed like an ideal solution. However, the SMART tables also worked using multi-touch rather

than pens. This required a substantial rewrite of CCW, a problem confounded by the usual issues of bespoke hardware drivers and operating system differences (the SMART tables have two hardware configurations, one used Windows 7 and the other used Windows VISTA, and both required slightly different code to make CCW work).

CCW was therefore changed from a pen-based application to a multi-touch one. This required the sacrifice of some of the advantages of the pen based interaction (identifiable users) but brought some of the advantages of a multi-touch interface (gestural interaction for resizing, rotation etc.).

4.7.2.2 The Classroom

One of the major practical issues of conducting a study in a classroom is the room itself. Ideally, a deployment such as this would be situated in a dedicated room not used for any other activity. In practice, this is not possible given the multiple demands for space in a school.

This leads to several issues, including availability of the room for study sessions, what to do with the equipment outside of study sessions and allowing setting up and dismantling time so the room can be used by other parties. Compounding these problems were the short notice changes that the school required to planned sessions due to rooms or storage areas being unavailable.

4.7.2.2.1 Room Availability

The classroom designated in the early planning (Figure 21) of the study was assessed, measured and checked for appropriateness (power outlets, safety etc.). Unfortunately, for several sessions, the planned room was unavailable. This lead to some sessions at short notice being held in different rooms, some of which were less appropriate.

Figure 21: Original Classroom

Two backup rooms were used, the first was a computer lab (Figure 22), and had many issues with regard to the study. The teacher was not able to move around the classroom due to restricted space, the computers themselves could not be removed and the layout restricted how learners could sit around some tables. This was also the room where the tables were stored between sessions (under the desks). The second backup room was a large classroom (Figure 23) that is usually arranged in a lecture theatre style, but with removable seating. This room was more usable, but required more setting up due to very few power outlets and the requirement of removing and then replacing the seating. It also had a disadvantage in that it was a "hub" room and there were connecting classrooms that were in use, causing traffic through the room at the start and end of the session.

Figure 22: Computer Lab

Figure 23: Large Hub Room

4.7.2.2.2 Storing the Tables

Between sessions, the tables and other equipment had to be dismantled and stored so that the classroom could be used by other groups. In most cases, the tables were stored in the computer lab (Figure 22), as they would fit under the desks without disturbing other computer lab lessons. However, on a couple of occasions the computer lab was in current use when the tables needed to be moved. This meant that the tables had been spread around other adjoining rooms, including cupboards and teachers offices.

4.7.2.2.3 Setting Up and Dismantling

As it was not possible to have the tables in a permanent setup, for each session the classroom furniture would need to be cleared, the digital tables would need to be removed from storage, taken to the classroom, laid out with appropriate seating, cabled up to power outlets and finally the cabling to be made safe by taping down with gaffer tape. Then the tables could be switched on, calibrated and updated with the content for the session. This process took around one hour for two researchers to complete.

As well as the tables, recording equipment would be set up (two or three cameras plus audio recording for tables and teacher). Necessarily following a session, the whole deployment would need to be dismantled and put back into storage. Usually, the room was free for one hour before and after, allowing just enough time for two researchers to complete the task. However, on two occasions the time available was only thirty minutes, requiring help from teachers and students to complete the setup.

4.7.2.3 Table Calibration and Reliability

The SMART tables, despite being mobile, are not designed to be moved frequently. This meant that they often needed recalibration before each session. They were also very sensitive to finger size, meaning a calibration done by an adult may not work well for a student when they came to use the table. The calibration was also sensitive to ambient light, so if the weather became sunnier or darker outside, then the tables may need recalibrating. In general, the responsiveness of the tables was very variable, and sometimes very poor, frustrating the students.

In addition to this, the SMART tables had an issue with turning on. The table consists of a projector and a PC internally, and sometimes one or either would not start up when the unit was turned on. This meant the table would need to be opened up and switched on internally, something which non-technical users do not find comfortable.

4.7.2.4 Recording

Recording of sessions was done with two or three cameras (one classroom camera and one or two table focused cameras), and audio recording devices on one or two tables. The practicalities of the scenario, in particular room size and set up time

restricted the number of cameras used, and the practicalities of the subsequent analysis requirements lead to the decision to use this number of cameras.

As part of the instructions given to the students, they were informed that their participation (and the recording thereof) was optional. Several groups decided that they did not want to be audio recorded, and so turned off their audio recorders, however they sometimes did this autonomously without informing the researchers.

4.7.2.5 Scheduling

Aside from issues with the rooms, the scheduling was a big issue with the study. Initially the study had an agreed schedule with more sessions, but school events and the onset of exams required that the schedule was changed several times during the study, and on one occasion just before a session was due to take place. This meant that the study was not as longitudinal as had been designed.

4.7.2.6 Cooperation of Teachers

If the teachers cannot see the value of a particular task, they are less likely to engage with the process. It is of course the responsibility of the researchers to make a convincing case for a particular activity, as teachers are the ones with the day-to-day experience of working in a classroom, and have a good feel of what works and what does not. On a couple of occasions, there was a disconnect between the researchers and the teachers. Firstly, during the initial stages when the research team was explaining the technology and how to use it, one of the teachers did not engage and left after a short amount of time (and later in the study this caused issues when using the technology). On a second occasion, one teacher decided not to use the planned Pupil View Template, replacing the task with one of her own devising, making the analysis of this data more difficult. On both these occasions, the research team had not conveyed the significance of these activities sufficiently to avoid these pitfalls.

4.7.3 Improvements in Research Approach

In order to improve the approach to this kind of study, these issues need to be addressed.

4.7.3.1 Issue 1: Planning and Implementation of deployment

To ensure a better deployment, the room allocation and scheduling should be agreed with the partner school in advance for every session. However, the reality of school management is that this is not always possible and changes will need to be made during the study. Therefore, building redundancy into the study will be necessary – having extra sessions in the plan from the beginning will allow for flexibility in the study.

4.7.3.2 Issue 2: Improved software design

Issues such as visibility, progression and assessment came up during the study as areas for improvement in the software design. Students had issues with the connection phase, in particular when they had already spatially arranged paragraphs but were required to break this arrangement to connect. With regard to assessment, producing a written piece of work in a group makes it hard for teachers to individually assess students. It is also a point in the design that encourages one particular student to "take over" as there is only one document to be typed into. A better design would allow for individual writing based on a collaborative planning stage. Individual assessment also gives students more purpose (i.e. issue 7).

4.7.3.3 Issue 3: Teachers gaining experience in using the technology

In the study, although the students had multiple sessions with the task, the teachers did not. This was also a factor in why none of the teachers felt they owned the technology (issue 5). The issue is not one of training, as it is not the use of the technology per se, but its integration into a real classroom scenario that is the challenge. Focussing on a single class and a single teacher through multiple sessions would go some way to alleviating this issue.

4.7.3.4 Issue 4: Understanding the limitations of the technology

Related to this issue, and understanding of the technology and the constraints with regard to the teacher's role in the classroom would help to alleviate some of the misplaced perceptions about responsibility. The teacher should be and is in control of the technology, and this sense of control is a key ingredient of the feeling of

ownership (issue 5). Once a teacher knows what the technology can and cannot do, they can plan their use of it accordingly.

4.7.3.5 Issue 5: Give Teachers ownership of the technology

This is perhaps the biggest challenge to overcome to make a successful study. Solving the other issues would go some way to overcoming this obstacle, but it also requires enthusiasm and vision from the teachers involved. The key is for the teacher to feel like they can use the technology for their own ends, i.e. their own ambitions and agenda for the class. The key for the success of the technology is not just the physical integration, but the conceptual integration into a teacher's thinking. To this end, a collaborative research relationship with the teacher will be required, incorporating two-way communication (so the teacher can influence design) and planning exercises (so the teacher and researchers can explore scenarios where the technology can be used best).

4.7.3.6 Issue 6: Reliable Technology

Although a low-level issue, the reliability of the technology was a significant impediment in the study. It was largely a factor of the hardware used, though some design improvements can be made (issue 2). Fortunately, after the study, the manufacturers of the hardware have released an improved hardware interface, and future studies should have much more responsive tables.

4.7.3.7 Issue 7: Give students' work purpose

The suggested improvements in design (allowing for individual assessment of writing as well as the collaborative planning), along with careful rephrasing of how the study is presented to the students will go some way to making the tasks seem important to students. However, the biggest impact would be if the teacher establishes that the work on the tables is integrated with their overall teaching agenda, i.e. incorporated into their curriculum goals. This relies largely on giving the teacher ownership of the technology (issue 5) as this would naturally lead to integration into lesson plans and assessment schedules.

4.7.4 Improvements in Data Collection

One of the aims of the study was to evaluate the collaborative writing application in an "in the wild" setting, i.e. the classroom. Some of the factors outlined above affected this aim, but there are also improvements that can be made in the area of data collection.

The first is to ensure that data required for analysis is captured. In the study, students were informed that they were allowed to opt out at any time, and most of them did with regard to audio recording, making analysis difficult. This is a reflection of the relationship that had been established with the students. Their disposition, as can be seen in the analysis, was that the study was not *for* them, and as such, it was an imposition. Establishing a collaborative relationship, more like a partnership with the students, to engage them as researchers, would make it more likely that they would accept recording of their activity.

The second improvement is selecting which data to collect. The experience of running a classroom-based study has shown that due to space and time requirements (i.e. the ability to deploy recording devices such as video cameras and audio recorders), a targeted data collection policy is more appropriate rather than attempting to capture everything. This was indeed the case in this study, where only single tables were monitored each session (rather than a camera per table, for instance). However, the table and group were different each session. This was intentional, to get a good overview of the class as a whole. In retrospect, this was not optimal, as it was treating the *class* as the unit of analysis. Instead, following a single group (i.e. the group is the unit of analysis) allows researchers to follow progress in more detail. To obtain an overview of the classroom, however, other data sources must be used, such as a classroom video camera, and crucially, data from the teacher such as lesson plans and reflections.

4.8 Conclusion

This study aimed to address the research objectives of adapting the collaborative learning design to the reality of the classroom and available and examining the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment. Ultimately, the study was dominated by issues around the second of these objectives, which coupled with the data collection strategy

employed, meant that evaluating CCW (in terms of collaborative behaviours) was not achieved.

Therefore, two key factors can be taken into the next study. Firstly, the lessons learned from this study (i.e. the specific issues outlined above resulting from mismatched expectations of different stakeholders – based on findings from the PVT analysis, teacher interviews collaboratively analysed in [58] and direct teacher questioning about responsibilities). Secondly, a different approach to data collection that focuses on a single group across the study. Addressing these factors should provide the data necessary to evaluate CCW.

Chapter 5

Study 2: School Two

As the study outlined in chapter 4 did not provide enough data to fully evaluate the collaborative writing application, a second study was required. Building on the lessons learned from the previous study with regard to the challenges of a classroom deployment (including data collection), the approach is modified, resulting in a richer group-level data set, and a more teacher focused classroom-level data set, enabling such an evaluation to take place.

This study, by again by utilising an "in the wild study" in a classroom to address the research objectives:

- Adapt the collaborative learning design to the reality of the classroom and available technology – by utilising more commonplace technology (i.e. SMART tables) and adapting the design of CCW to the technology and environment (i.e. version 1.2).
- Examine the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment – by recording the progress of the study from multiple viewpoints and deriving key issues to be addressed in such a deployment.

Again, the study aims to evaluate CCW in terms of collaborative behaviours (as opposed to improvements in the writing task, which would require a much larger study to ascertain), when situated in the classroom.

5.1 Revisiting "In the Wild" – Changes to Approach

It is clear from the previous study that the initial approach to the study was not optimal. There are several areas where improvements could be made, and the previous study is valuable for refining the approach for in the wild classroom studies.

To improve the approach for future studies requires revisiting some of the areas that the previous study highlighted as being problematic. Some of these areas are simply a matter of better planning, bearing in mind the dynamic nature of the school environment. Any new study should be flexible (i.e. able to adapt

easily with circumstances), have contingency built in (for failures in technology, scheduling, room availability etc.) and enough redundancy that a good number of sessions is still possible if (for whatever reason) sessions are postponed or cancelled.

More challenging is improving the performance of the study itself. This requires a different, more robust and well-defined approach to the relationship between the parties involved – The School, Teachers, "Academics" and the Learners themselves. To this end, it is helpful to think of all parties as researchers, not just those from the academic institution. One of the first priorities then is to build up this "we are all researchers" relationship with the school and especially the teacher, by involving them in the planning from the outset, and being honest and explicit about all parties expectations from the beginning. This means discussing limitations as well as functionality of the technology, defining responsibilities for vital classroom aspects (such as orchestration, regulation of behaviour etc.) as well as finding aspects of the research that interest the teacher and learners.

Looking back at the previous study, this relationship was not established. Goals, expectations and responsibilities of all parties were not defined explicitly – and this led to incorrect assumptions and misconceptions about the study that affected its performance. For this subsequent study, the approach attempts initially to address these issues by changing the relationship between the school, teachers, students and academics, as well as changing the software design based on the previous study and discussion with the teachers involved.

5.1.1 The School

For this second study, a different school was chosen. This was due to the unavailability of the first school, who were initially approached for this follow up study. The second school underwent an Ofsted inspection in October 2013, soon after the study took place [90]. The report describes the school as:

> "*The School is a larger than average-sized secondary school and has a large sixth form... Proportions of students supported through school action, school action plus or with a statement of special educational needs are all below average. The proportion of students known to be eligible for pupil premium*

is below average... The school meets the government's current floor standards, which set the minimum expectations for students' attainment and progress. The School converted to become an academy in February 2012. When its predecessor school, of the same name, was last inspected by Ofsted it was judged to be outstanding."

The report goes on to award the school "outstanding" ratings in overall effectiveness, achievement of pupils, quality of teaching, behaviour and safety of pupils and leadership and management.

The initial contact with the school was made with their head of Information Technology, who was interested in the technology. An initial meeting was arranged with a group of interested teachers from the English department and university researchers. Informed by the previous study, the meetings were less focussed on the technology, aside from highlighting limitations and capabilities, and more focussed on the teachers' agenda (of teaching Extended Writing composition to her class) and what they thought they could get out of the study.

It was agreed during discussion with the school that to get the most out of the study for all parties, the study would focus on a single class and a single teacher. Several subsequent meetings were arranged to establish a solid plan with the teacher, all held at the school.

It was also agreed that the sessions would take place in a single classroom, though it would not be possible to leave the tables set up in between sessions, although they could be stored in an adjacent storage room. This meant that, as in the previous study, the tables would need to be set up and dismantled for each session. To allow for this, it was arranged that the classroom would be free for one hour before the sessions, either during a lunch break or by booking the classroom for two periods. Dismantling would have to be achieved before the next class arrived, however. As in the previous study, this restricted the set up time and limited the amount of recording technology that could be feasibly used per session. It was agreed that recording equipment would be restricted to two cameras and one audio recorder.

The school gave the impression that their culture was concerned with both attainment and skills development (i.e. both acquisition and participation [118]).

The teacher was concerned with both covering the curriculum material and strengthening the transferable skills of the students for use across the curriculum and generally in their lives. In particular, the teacher highlighted the usefulness of being able to write well in a persuasive manner across a range of subjects other than just English.

5.1.2 The Teacher

Working with a single teacher allowed for more focussed planning and establishment of a more cooperative relationship. Planning sessions revolved around the teacher's expectations and requirements from the series of lessons.

The limitations as well as the capabilities of the technology were discussed, with particular regard to issues that had occurred in the previous study. It was established that the digital tables do not regulate behaviour on their own, and researchers shared their experience of common misbehaviours (such as "flicking" objects round the screen, hiding objects on purpose etc.) and highlighted how to identify them by observing the tables' displays. Researchers also indicated how to ascertain progression by viewing the tables' displays, indicating that the interface was designed to be cumulative. This led on to the more general topic of orchestration [27]. Both parties agreed that technology enhanced orchestration might be desirable, but that ultimately, the study needed to focus on the tables themselves, and adding technology supported orchestration would complicate the teacher's role. There is scope for further studies in this area.

As the emphasis on the technology is now on not only the learners' needs but also how the teacher can wield it effectively, consideration of using technology to add value to the teacher's existing work is required. To this end, the teacher agreed to integrate the technology at the lesson planning stage. The lesson plan is a tool the teacher already uses to regulate the learning agenda, and has well defined goals and outcomes for each session. Integrating the technology into the plan, with an explicit intention for specific goals and outcomes, could prove fundamental to the success of the technology, and is could be key to the ownership by the teacher.

Discussions with the teacher around CCW also produced some changes in the design (to produce version 1.2). The teacher indicated that having part of the task being individual, i.e. the final writing stage, was a good idea, as it would

motivate students to participate and allow for assessment. The teacher also suggested that the ordering of the stages should more closely match the manner in which the concepts are introduced in the classroom. That is, rather than progressing in difficulty from reading evidence, creating paragraphs, inserting evidence and finally connecting paragraphs, as it was in the first study, CCW version 1.2 should progress conceptually. Looking at how writing is normally introduced to students, the connectivity stage should come before the insert evidence stage, as tying a document back to the evidence is a concept the students are exposed to later in the process. These flaws in the design may have contributed to problems seen in the previous study.

The classroom where the sessions were to take place was not the teacher's usual room, and it was sometimes occupied by another class. This meant that the initial plan of having two table sessions a week was un-workable, and a one session per week plan was devised. As each session of the writing application requires a previous session dedicated to generating material to write about, and these are usually Digital Mystery sessions that also require tables, it was decided to have an additional "classroom debate" session outside the tabletop sessions. This would be the final non-writing session, so that the students would have good experience of the technology before their lesson format changed. Given the available schedule, it was decided with the teacher to make the most of the available sessions by concentrating on CCW and omit activities such as the PVTs from the previous study. Instead, the teacher would monitor feedback from the students during the sessions, and include a short feedback exercise in the final session to elicit the students' opinions of the positive, negative and interesting aspects of the study.

5.1.3 The Students

When engaging the students, the approach was more involved than in the previous study. Firstly, the teacher and the university researchers introduced the study together to form a "united front", making it clear that the teacher was a partner in the study and not being subjected to it from outside. Next, it was made clear to the students that they were also partners in the study in the sense that they were helping to test the technology for a research purpose as well as their own learning.

When CCW (1.2) was introduced, the fact that the final writing stage was individual and would be assessed by the teacher encouraged students to engage with the task from the outset. Finally, the students were informed, as in the previous study, that the recording of the session was voluntary and they could opt out. However, unlike the previous study, they were asked to make this clear from the outset rather than on a session-by-session basis if possible. During the study, no student changed their mind and asked not to be recorded.

5.1.4 Changes to CCW Design

Following the previous study, and discussions with the teacher, the writing application design was changed to focus on *planning* of a document. This allowed easier integration into lessons, where individual written work may be needed for assessment purposes or when multiple planning exercises might be undertaken without progressing to the final writing. It also removed the final text-generation stage, which as seen in the previous study, focussed on a single "scribe" and therefore did not encourage full group engagement. This refocus on planning allows students to develop essential planning skills – high levels of planning are especially apparent in the composing behaviour of skilled writers [72]. Plans developed in the writing application are then available for individuals to complete a separate writing phase as the lesson required. Additionally, the connective stage was altered so that the spatial arrangement of paragraphs was not lost (this had been confusing for learners in the previous trials [45,58]). The connection stage also occurred before inserting evidence, and after discussion with the teacher, as this was a more logical progression. (In the previous study, the order of the sub-tasks was based on perceived difficulty, such that the "hardest" sub-task, connecting, was last).

Following the previous study, and with input from the teacher in the current study, it was decided that CCW should concentrate entirely on the planning stage of the writing process, rather than allow for text generation or drafting. Applying this this to the modified diagram derived from Coffin et al. [20] gives a final mapping for CCW (Figure 24):

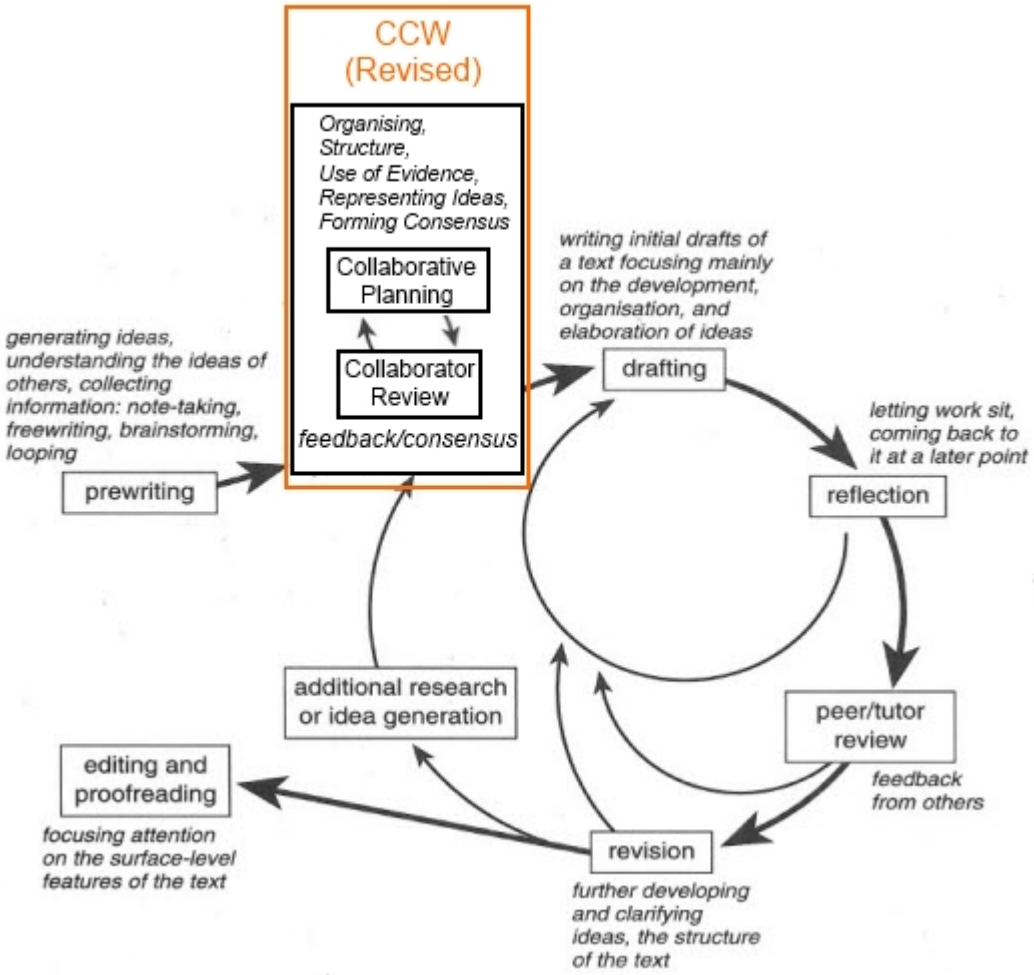


Figure 24: Coffin et al. Writing Process - CCW Revised Mapping.

5.1.5 Final Design Overview

The final design (version 1.2) incorporates four main stages, a Review Evidence stage, a Paragraph Creation stage, a Paragraph Connecting stage and an Including Evidence stage.

5.1.5.1 Reviewing Evidence

The first stage allows users to review evidence data items generated from a previous activity (for example Digital Mysteries [60]). Evidence is presented in three views, as a palette of data items (Figure 25), as a list of full outlines (Figure 26) and a snapshot of their previous Digital Mystery outcome (if one was completed). Moving to the next stage requires users to agree using a decision point dialog box (asking if all participants want to proceed) – which disables the rest of the interface so that the group must focus on the decision.

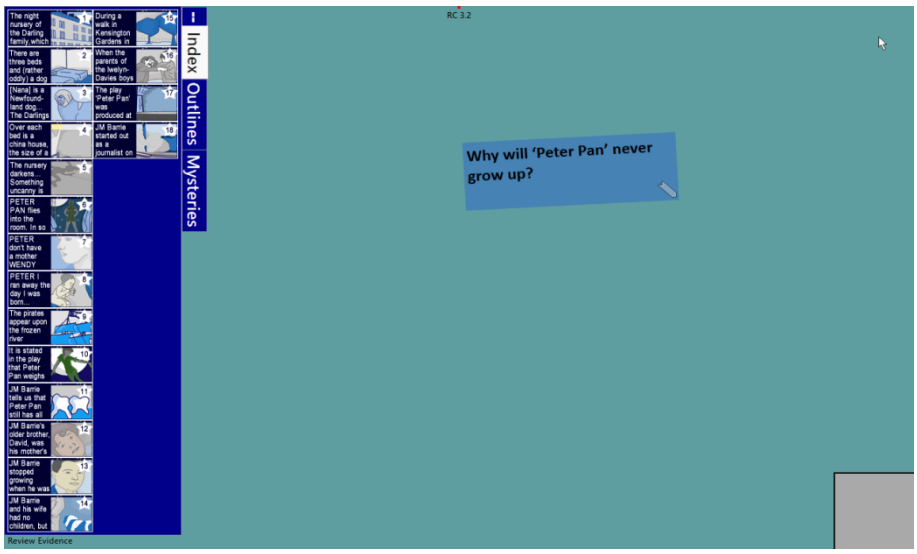


Figure 25: Review Evidence - Palette of Evidence

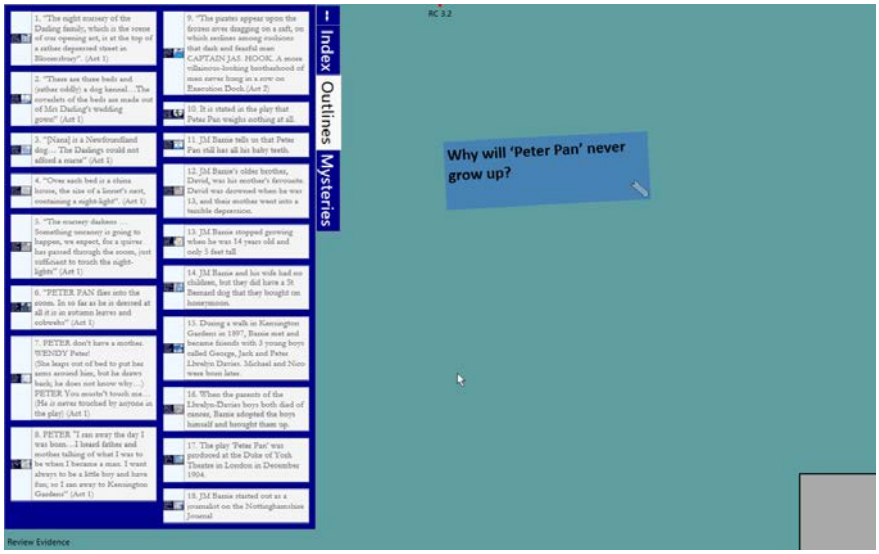


Figure 26: Review Evidence - Outlines

5.1.5.2 Create Paragraphs

The second stage is about making paragraphs, and adds the functionality of creating paragraphs (without removing any other functionality – CCW 1.2 is cumulative). Initially two paragraphs are provided – Introduction and Conclusion (Figure 27). Users can use the menu to create new paragraphs. CCW 1.2 then brings up a decision point dialog box (Figure 28), prompting for a paragraph name. During this dialog, all other interactions are disabled, so the group are focused on the decision – what should be the name of the new paragraph? Users can also use a thinking hat [12] icon to describe the kind of language to be used when writing the content for the paragraph. Again, to progress to the next stage, the group must decide via a decision point.

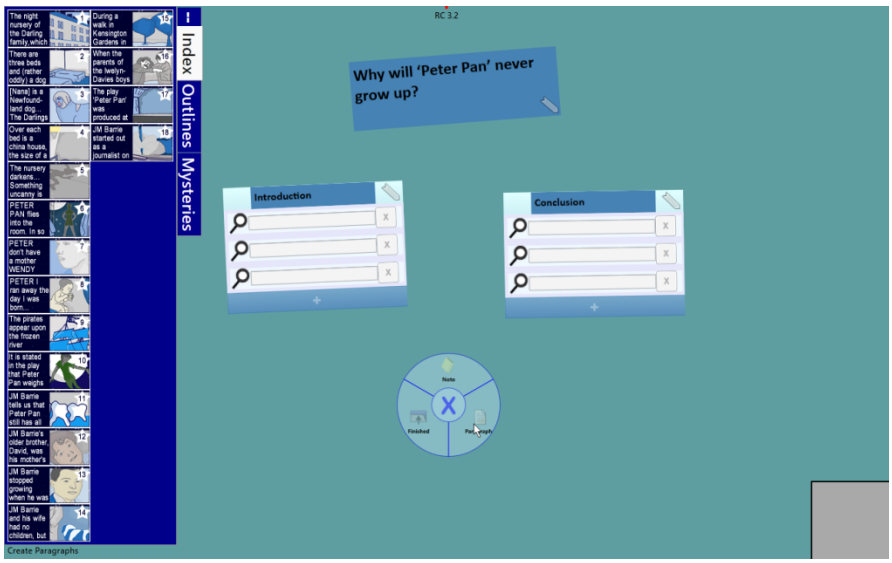


Figure 27: Create Paragraphs

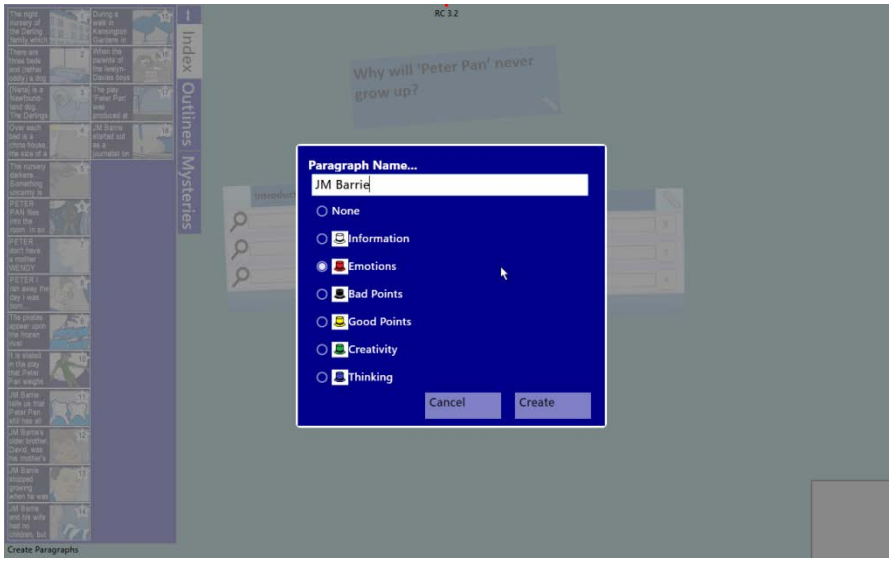


Figure 28: Create Paragraphs - Dialog

5.1.5.3 Connecting Paragraphs

The third stage allows users to connect paragraphs together. This was accomplished by selecting the connection token in a paragraph then dragging this to another paragraph to make the connection (Figure 29). This allows the paragraphs to remain in their existing spatial arrangement – which is less confusing for learners (particularly in groups where the interface is a shared cognitive space) who may have already made a spatial representation using the paragraphs to externalise their impression of the document. Making a connection brings up a decision point dialog box (Figure 30), asking users to identify the relationship between the connected paragraphs using a connective word or

phrase. To progress to the next stage, users must again go through a decision-point dialog box.

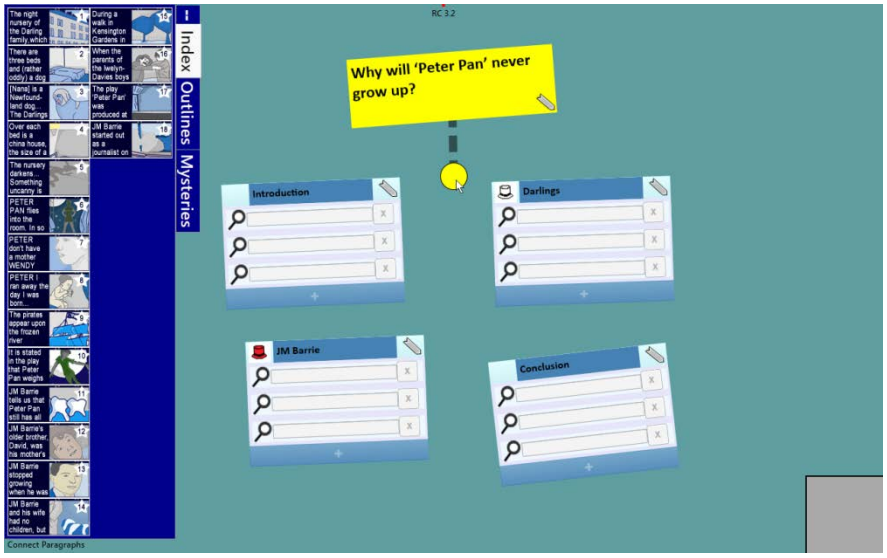


Figure 29: Connecting Paragraphs

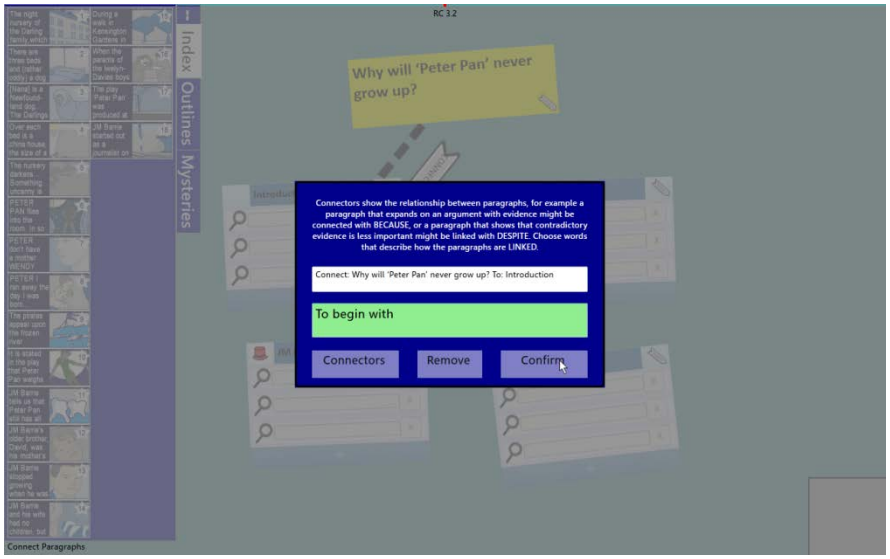


Figure 30: Connecting Paragraphs - Connection Dialog

5.1.5.4 Including Evidence

The final stage allows users to include evidence into their paragraphs as outline points, or create their own outline points by typing (Figure 31). Evidence data items are created by selecting from the palette, and included by dropping the evidence in the paragraph.

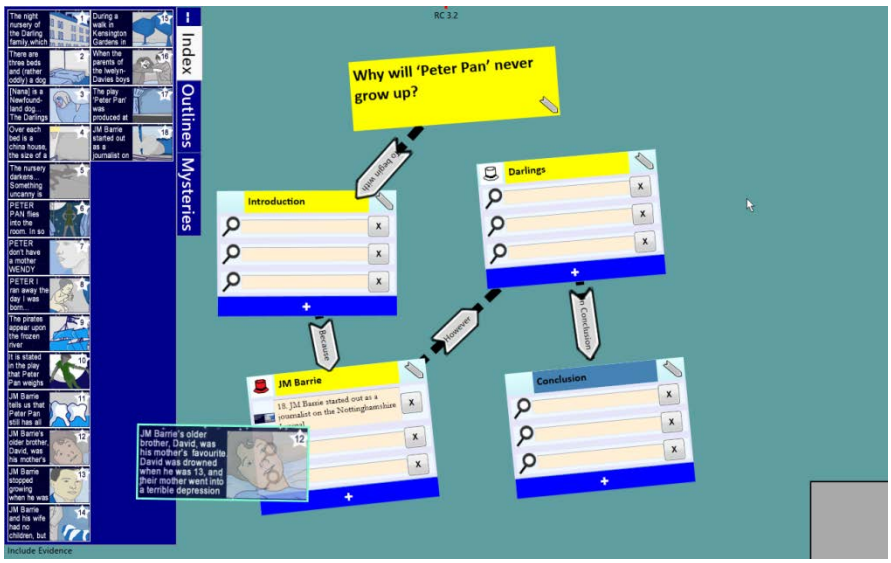


Figure 31: Include Evidence

5.1.6 The Technology

Another issue that occurred in the previous study was the underlying reliability and sensitivity of the digital tables. Despite being a low-level issue, the impact on the study was high. To address this, the manufacturer serviced the digital tables prior to the new study. This involved replacing the touch interface with a more reliable technology. Overall, this greatly improved the interaction with the tables, though it was still not perfect – and some reliability issues still occurred.

5.2 Study Design

The study was conducted over four sessions across a half term (6 weeks) in a secondary school classroom. The classroom was equipped with 8 smart tables, allowing upto 8 groups of 3-4 students to participate – 30 students in total. The students were mixed ability year 8 (aged 13-14), studying English. Groups were consistent across the study and were decided by the teacher to represent the mixed ability nature of the class. The same English teacher, with over ten years of experience, facilitated each lesson. Sessions were scheduled to fit in with the existing timetable – the teacher worked with the technology before the study and designed lesson plans to incorporate the technology into the teaching agenda. 2-3 Academics were also present, and sessions were filmed. Before each writing session, the students completed a collaborative exercise, either a Digital Mystery [60] (first 3 sessions) or a classroom debate (for the final session).

Classes	Students Per Class	Teachers	Subjects	Tables	Sessions
1	~30	1	1	Up to 8	4

The Digital Mystery activity allowed the students to address a specific question by manipulating, grouping and connecting "data slips". These data slips were then directly reused in the writing task as "evidence" (Figure 32). (The full Digital Mysteries used are shown in Appendix A: Digital Mysteries).

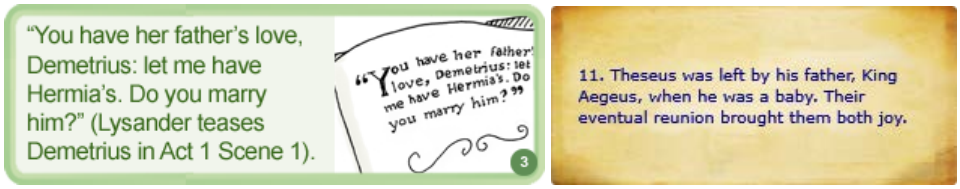


Figure 32: Example Digital Mystery "data slips" from Midsummer Night's Dream and Greek Mythology Mystery,

5.2.1 Data and Analysis

Several data types were recorded during the study. Classroom sessions were filmed with a single camera, one individual group was filmed with a single video camera, and audio was recorded for both the classroom (through the classroom camera) and the individual table (with a separate audio recorder). The teacher provided lesson plans and teacher reflections from each session, incorporating her impressions of progression of students from marking outputs and feedback.

The data types allow for multiple perspectives for analysis. These perspectives are closely linked to the orchestral concept of planes, identified by Dillenbourg and Jermann [27] and further developed by Kharrufa et al. [59], which suggests that activity in the classroom is expressed across multiple planes: Individuals, Groups, Teacher and Classroom. In their work, planes are used as a fluid concept rather than discrete categorisations, activities can register on multiple planes and can transition between planes (i.e. begin in one plane and end in another). Planes give a broad concept for overall activity in the classroom, and it is useful to think of the different data types as loosely connected to particular planes.

The classroom camera recordings, for example, can be thought of as acting on the "classroom" plane, but within this data will be episodes of individual, group and teacher actions, but in the context of the classroom – the level of detail will be

appropriate for the classroom plane, but not necessarily the other planes that are captured. Likewise, teacher plans and reflections inform primarily the teacher plane, but will also include insights into other planes. Interaction logs from the tables can be observed on the classroom plane (by comparing them across all groups) but could also show group behaviour. If the technology allowed for individual identification, then it would also touch on this plane as well. The individual table video, audio and interaction log provides a case study into the specific interactions and learning activities experienced primarily at the group level, but also captures individuals. Table 19 illustrates this concept. The table identifies primary planes in which the context of the data is valid, and secondary planes in which insights are expected. Planes identified as tertiary indicate that there is a possibility of meaningful overlap, while N/A signifies no expected overlap.

		Plane		
		Classroom	**Teacher**	**Group**
Data Source	**Classroom Camera**	**Primary**	Secondary	Tertiary
	Teacher Plans & Feedback	Secondary	**Primary**	Secondary
	Interaction Logs	**Primary** / Secondary	N/A	**Primary** / Secondary
	Table Camera & Audio	N/A	Tertiary	**Primary**

Table 19: Data Capture Methods across Planes

The aims of the analysis are twofold, to evaluate the writing application in the context of the classroom, but also to more generally investigate the integration of the technology into the "in the wild" setting across the four planes outlined above. For the primary aim, it is necessary to ascertain if the design elicits collaboration, and the analysis process should look at what collaboration took place, the quality of this collaboration and whether the design of the writing application influenced (or enhanced) this collaborative process. The secondary aim is linked to this, as it depends somewhat on a successful application. It also

includes additional factors such as the reactions of the teachers and the students to the technology and their general behaviour in the classroom.

5.2.1.1 Teacher Plans and Teacher Reflection

The teacher prepared detailed lesson plans prior to each session (An example can be seen in Appendix D: Example Teacher Plan). She also provided detailed reflections after each session, which incorporated her impressions of student feedback, plans and written work resulting from the sessions (an example of which can be seen in Appendix E: Example Teacher Reflection and an example marked essay from the final session can be found in Appendix G: Example Marked Essay).

Lesson plans and teacher reflection are analysed using an inductive thematic analysis, incorporating initial encoding, listing of candidate themes and application of the themes across the data, as suggested by Braun et al. [13].

Although the study is focused on the *quality of the collaborative behaviours* around CCW 1.2, the teacher provided feedback according to her own agenda – including her impression of student progress and attainment in the writing task. Although these factors can't be tested objectively given the scope of the study (both in length of time, number of participants and lack of a control cohort), the teacher chose (unsolicited) to include her impressions (as a domain expert) of what she thought the impact of the work was having on the students. The analysis produced the following themes:

- *The Technology*- where the teacher is concerned with the use of the technology primarily, rather than the learning task itself. This theme occurred more frequently in the earlier sessions.
- *Student Progress* – where the teacher talks about the impact of the task on students' attainment levels as defined by the curriculum.
- *The Writing Task* – the teacher is concerned with the actual learning task, i.e. learning persuasive writing. This theme became more prominent in later sessions, as concern about the technology faded.
- *Lesson Management* – the teacher is thinking about moment-to-moment lesson orchestration and how the technology-based sessions compare with "ordinary" lessons.

These themes are referenced in **bold** throughout the Results section - 5.3. Plans and teacher reflections typically showed the intention of the lessons, how the session is integrated within the curriculum, the teacher's opinion of progress of the students and the students' written work.

5.2.1.2 Students Interactions around the Digital Tabletop

Interaction logs were generated by the tables, and used to evaluate the task progress by showing time-stamped creation, manipulation and deletion of visuospatial elements, decisions made and text generated etc. This was analysed on a classroom plane as well as used to highlight group plane actions of interest.

For one group, video and audio were recorded (and transcribed) for each session - allowing observation of moment-to-moment dynamics of group-work in terms of multimodal interaction with and around the collaborative writing application. Figure 33 provides an illustration of how the view of the learners' interactions was synchronised with the annotation of their talk.

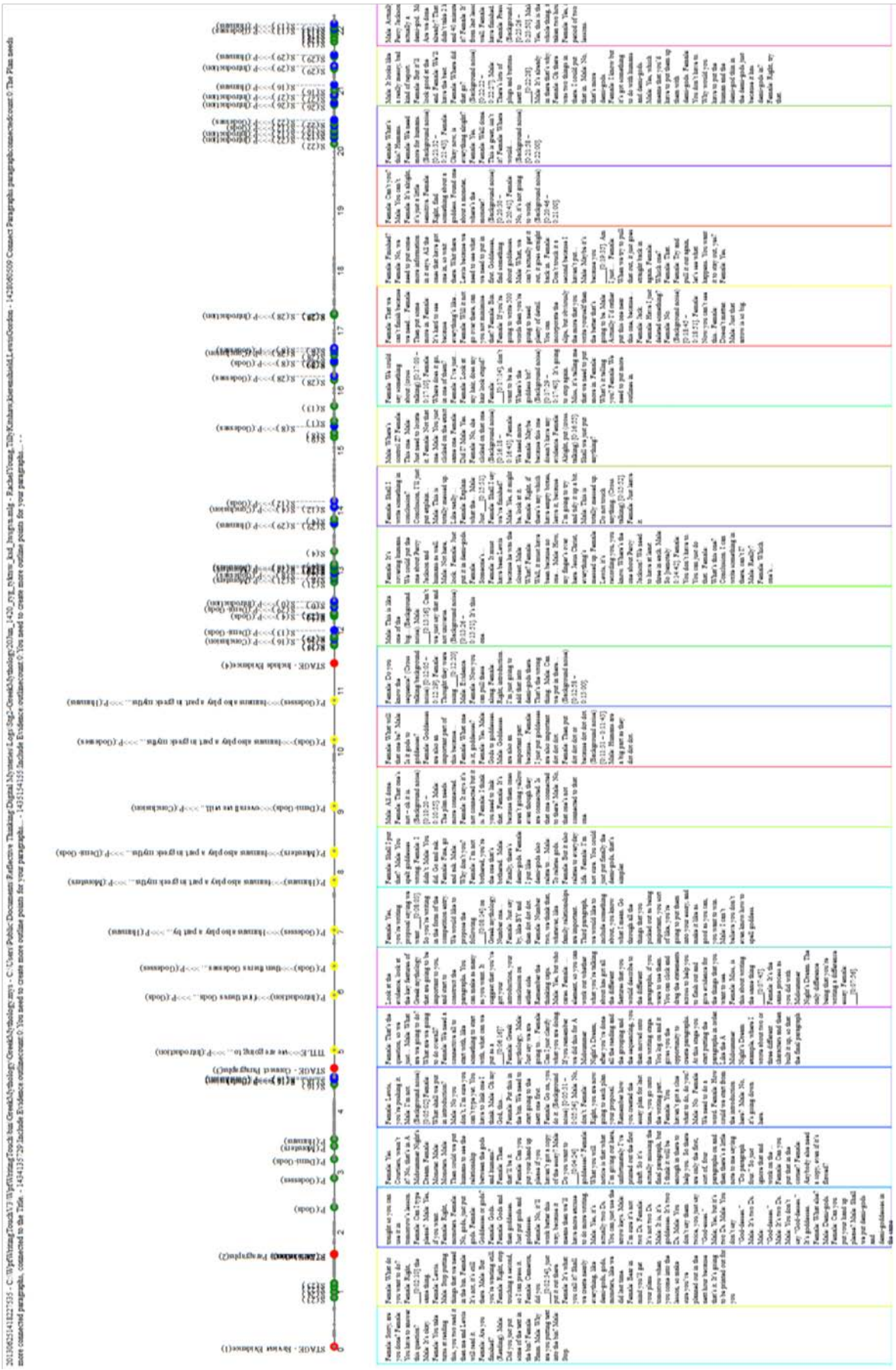


Figure 33: Integrated Interaction Log and Transcription

Video analysis concentrated on the multimodal interactions that formed the basis of the collaboration, especially around "decision points" (end stage, create paragraph and connect paragraph). Written transcripts of interactions on the table being video recorded throughout the study were analysed using methods from Discourse Analysis - which seeks to "explore the organisation of social interaction through discourse as coherent in organisation and content and enable people to construct meaning in social contexts" [22,42,121]. It examines language and sense-making practices as they are co-constructed across multiple modes of communication including speech, gesture and other contextual phenomena occurring in the spaces in which people interact [115].

The analysis comprised of two phases. First, an initial coding of interactional behaviours in terms of "proposals" was undertaken – as suggested by Barron [7], when looking at quality of collaboration and successful group work. The concept of proposals ties in with the writing application, which generates proposals around the decision points. Bartu [8] uses a similar concept of "propositions" when describing discourse during the process of decision making. For the purpose of this analysis, Barron's term "proposal" and Bartu's term "proposition" are understood to mean the same thing. The analysis attempts to answer three questions that arise from examining the discourse (in conjunction with table interactions):

1. "What types of decisions were taken in the life of this group? Why?"
2. "How were these decisions taken? Why were they taken in these ways?"
3. "What were the roles assumed by the group members? Why?"

Bartu presents an analysis methodology for encoding discourse, based on a "proposition" constituting an initiation, followed by negotiation (Clarification, Contribution, Acceptance, and Rejection), leading to finalisation or postponing of a decision (Figure 34). This process can be expanded to incorporate use of the table, and include the multiple propositions required to achieve a specific goal during use of the Collaborative Writing Application. Figure 35 illustrates the concept of multiple propositions taking place within the resolution of a collaborative writing goal in the form of a loop. Resolution is therefore a series of one or more propositions. The diagram also shows the role of the table in the discourse, as a scaffolding agent in the proposition stage, and as an implementer of decisions at

the resolution stage – at this point, the table is a tool rather than a scaffolding agent in the process. Propositions can also be prompted by facilitators; these were encoded alongside "proposals" created by the group or facilitator.

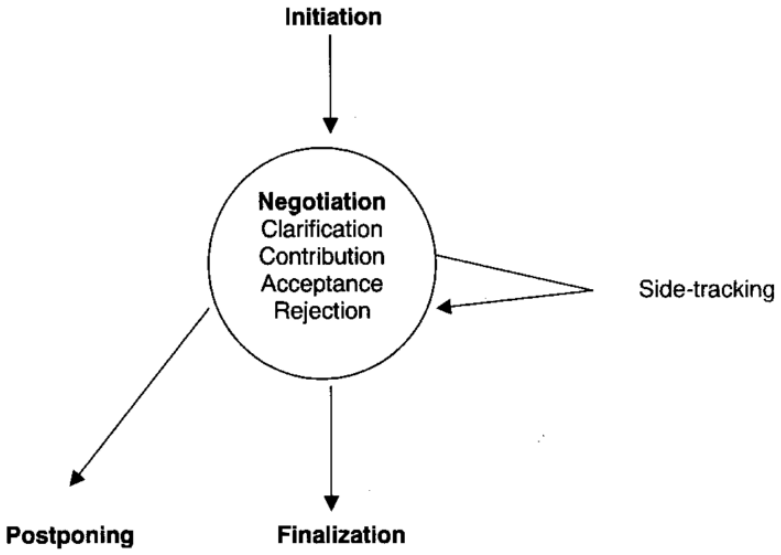


Figure 34: Bartu Proposition Diagram (From [8])

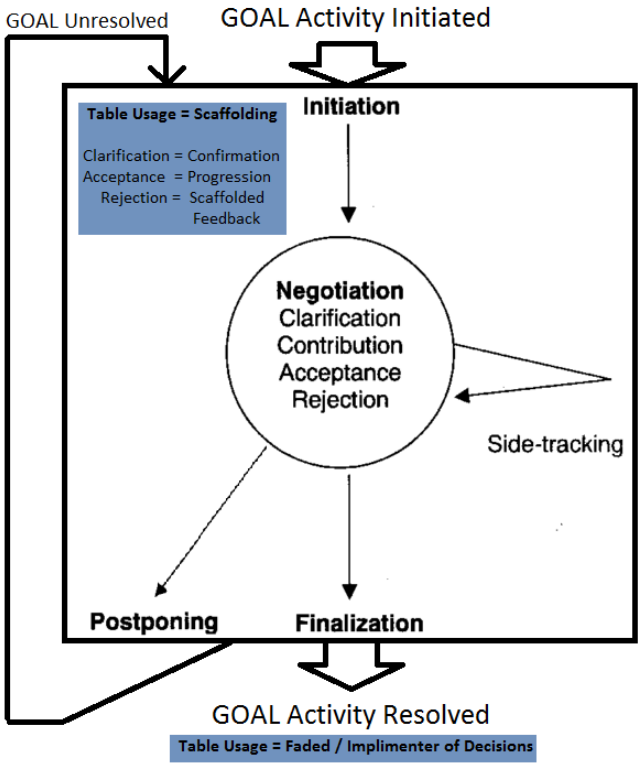


Figure 35: Modified Bartu Proposition Diagram incorporating Tables and Goal Activities.

5.2.1.3 Plus, Minus, Improvement

At the end of the study, the teacher asked the students to complete a Plus, Minus, Improvement (PMI) exercise. The exercise is a very simple way of getting feedback in a short time (compared with the Pupil View Template (PVT) exercises done in the previous study) – students only need to write one positive, one negative and one improvement statement. It lacks the contextual framework of PVTs, but gives a general experiential overview. An example of a completed PMI can be found in Appendix F: Example Plus, Minus, Improvement. Similar to the teacher's feedback, some of the students refer to their progress and attainment in the writing task – the scope of the study does not allow this to be tested objectively and the purpose of the PMI exercise is to ascertain the students impression of the study.

5.3 Results

The results of the analysis show the students' interactions (with the tables through interaction logs and with each other for one group through their discourse) and the teacher's plans and reflections on a session-by-session basis. The student interactions analysis for the single group (i.e. using the group as the unit of analysis) explores how proposals created by the facilitator, the writing application, and the group itself impact on the creation of a collaborative plan. The classroom interaction logs were also examined to get an overview of the overall class progress, and an impression of the kind of decisions students were making. The analysis also aimed to illustrate how the teacher incorporated the writing application into her teaching and the extent to which the writing application facilitated collaborative learning interactions.

Table 20 shows the number of turns and proposals occurring in each session across the data set, which were subject to double coding. Markee [77] defined a turn as "a spate of talk that is collaboratively constructed by speakers out of one or more TCU's", (Turn Constructional Units), "whose project-ability allows possible next and current speakers to identify when (a) current speaker's turn might audibly be coming to an end" (p. 84). The ways that proposals are performed varies according to the producers communicative goals (for example, as a question, exclamation, or imperative) [77].

The table, when taken in conjunction with other data sources, shows that the quantitative counting of turns and proposals is not enough to evaluate the quality and nature of collaborative actions. However, is give a basic insight into how many such events were occurring each session.

	Session Number			
Discourse Actions	**1**	**2**	**3**	**4**
Number of turns by students	233	125	292	260
Proposals from facilitator/s	9	18	10	19
Proposals from students	24	26	80	61
Proposals from students involving the table	8	19	43	53

Table 20 : Proposals and Turns by videoed group per session

5.3.1 Session 1 – A Midsummer Night's Dream – Part 1

The students worked on writing a persuasive document answering the question "Which character (in A Midsummer Night's Dream) is the most powerful?" (~20 minutes) based on a Digital Mystery they had completed in the same session (~45 minutes). The videoed group completed the task up to the point of paragraph connection (end of stage 2).

5.3.1.1 Teacher Interactions

In this first session, the first half of the lesson was spent undertaking the Digital Mysteries task. The teacher introduced the topic at the beginning of the lesson, using the board to write down key elements from the mystery. After this introduction, the teacher spent most of the mysteries session moving between groups. After around 40 minutes, the teacher took the students out of the classroom for a 10-minute break so that the tables could be prepared for the writing task.

For the writing task, the teacher began with a very short introduction, and then resumed the strategy of moving from group to group. To finish off the lesson, the teacher presented a 5-minute summary of the lesson, and prepared the class to resume the task next session.

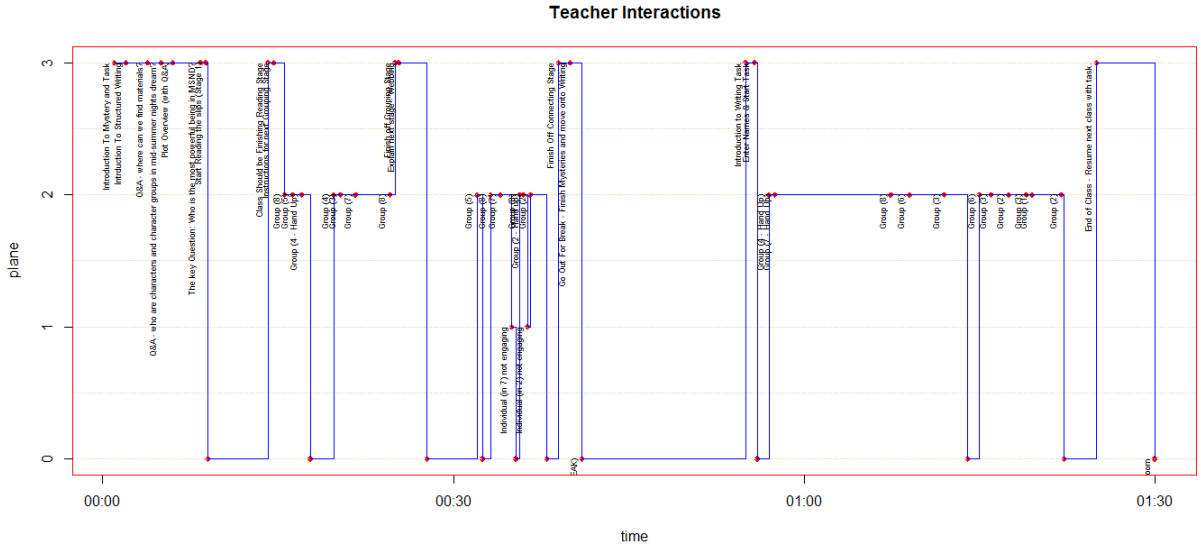


Figure 36: Teacher Interactions Session 1

5.3.1.2 Teacher Plans and Teacher Reflection

Initially, the teacher was tentative about the study, and this was reflected in her initial planning and reflection. The teacher's lesson plan is ambitious and suggests tasks around the technology (i.e. pre and post tasks) that were not possible in the timeframe of the lesson. The teacher reflection focuses on the theme of **Lesson Management**, firstly how to balance workload over time:

"…either allow more time, or limit the information they have to process… we don't want to remove detail and run the risk of limiting their achievement… I'd rather stretch the class than limit them" And how to implement differentiation: *"Where differentiation is required, encourage students to… create their own statements".*

The final thoughts on the session directly refer to aspects of **The Writing Task** and **Student Progress** themes, linking the connecting stage of the writing application with attainment goals:

"Connecting the paragraphs has been placed at the centre of the writing process…it's the linking and structuring of a text that is so important in achieving a level 6a/7"

This is an understanding on the part of the teacher that was not present in the first study, and is partially due to the teacher having earlier input into the design (i.e. the ordering of stages) to match her own agenda.

5.3.1.3 Interaction Logs

Interaction logs were recovered from seven tables. The interaction logs are again presented as a *timeline visualisation*, the purpose of which is:

- to give an overall impression of the classes progress with the task as a whole, i.e. how far did the groups progress;
- approximately how long did they spend on each stage;
- how many paragraphs or connections were made etc.

The timeline visualisation also highlights the *decision points* encountered during the sessions, i.e. Ending a Stage, Creating a Paragraph or Connecting a paragraph. Unlike the previous study however, as the grouping was consistent between the sessions (i.e. group at table 1 were the same each session, as were the group at table 2 etc.), the visualisation also allows tracking of these factors across sessions. Table 21 provides a key to the meaning of the symbols.

Symbol	**Meaning**
	New Stage (Create Paragraphs, Connect Paragraphs, Insert Evidence)
	Create a Paragraph or an Evidence Slip
	Create a Note or Get Scaffolded Feedback (i.e. Stage Criteria not met)
	Insert Evidence Slip into Paragraph
	Connect Paragraph to Document
	Delete Item
	Move an Item
	End of Session

Table 21: Study 2 Interaction Log Key

The purpose of the logs' visualisation is to give an overall impression of the class's progress with the task as a whole, i.e. how far did the groups progress,

approximately how long did they spend on each stage, how many paragraphs or connections were made etc.

The logs for this session show that only two groups completed the task within the time allocated. In this case, the Digital Mystery had been completed in the same session and the time available for the writing task was shorter than ideal, especially for a novel activity.

The teacher spent a few minutes discussing what would make good paragraph names, i.e. *on topic* and *related to the question*. Paragraph names produced by groups were a mixture of "on topic", such as Group 1 who came up with "Oberon and Titania" and the more generic such as "our opinion" (also group 1). After some prompting, group 1 began to alter their paragraph names to represent the different parties in the story ("workers", "magical people"). The group did not make any connections.

Of the groups (groups 2 and 4) that did make connections, most used the "built in" default connections. They were mainly used correctly, indicating that the concept at least was understood.

Groups that inserted evidence largely did so towards the end of the session, so paragraphs were not completed. However, the insertions that did take place were largely contextually correct (i.e. they fit in with the paragraph titles to some degree).

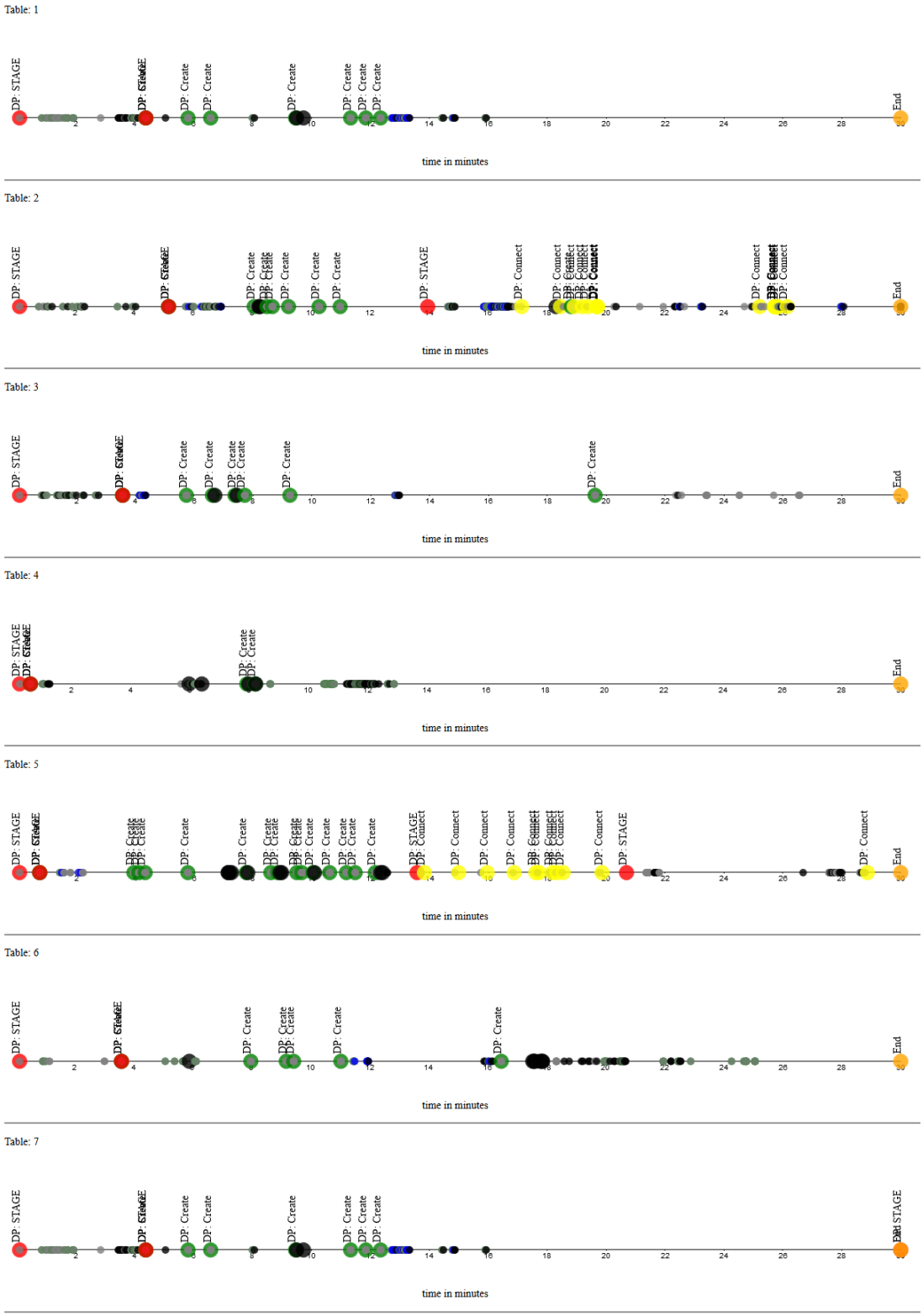


Figure 37: Session 1 - Midsummer Night's Dream Part 1

5.3.1.4 Decision Points

The timeline visualisation of the interaction logs shows when decision points occurred during interaction with CCW, however it does not show the nature of the decisions made (i.e. how it affected the group), who instigated them (facilitator,

student or CCW itself) or how timely they were in the decision making process. As the same group (i.e. table one) was filmed across the sessions, the decision point interactions can be investigated in more detail. An initial classification of the decision point interactions allows some of the questions (instigation, timeliness and nature) to be addressed, and highlights potential episodes for deeper investigation. Decision point interactions can therefore be classified as:

1. Facilitator Intervention – a facilitator directly instigates the decision point.
2. Individual Interruption of group – parallel working is interrupted by instigating the decision point without discussion.
3. Pre-Decision – the group decide to proceed but no "on topic" discussion occurs (i.e. mechanical process but NOT content).
4. Synchronised – the group decide to proceed while discussing how (i.e. process AND content).
5. Post-Decision or Implementation – the group decision is made off-table and CCW is used to IMPLIMENT.

For the first session:

Decision Point	**Classification**	**Description**
Reading Stage End	Facilitator Intervention	Facilitator moves group onto next stage.
Create Paragraph	Facilitator Intervention	Facilitator explains paragraph creation and creates first paragraph for group.
Create Paragraph	Pre decision	Group decide to make a new paragraph before deciding what to call it.
Stage End	Interrupted	One member is not ready and cancels stage end
Stage End	Synchronised	Second attempt and all agree to continue
Create Paragraph	Facilitator Intervention	Facilitator suggests paragraph topics based on information on the board
Create Paragraph	Facilitator Intervention	Group go on to create 2nd paragraph based on information on the board
Create Paragraph	Facilitator Intervention	Group go on to create 2nd paragraph based on information on the board

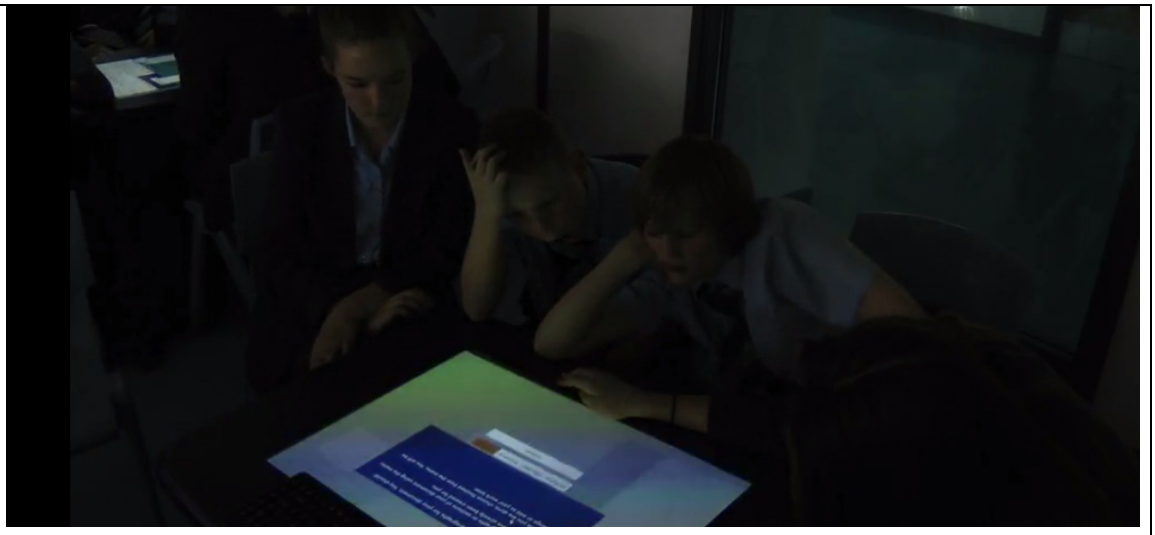
5.3.1.5 Single Group Analysis

This episode was chosen to represent the interaction between the group, the table and the facilitator during the session. Proposals were generated by both the interface (prompted by paragraph creation and decision points) and facilitators (Table 20). Proposals lead to discussions, although those from facilitators were accepted without much discussion. Episodes from the data are selected to be representative of the session as a whole, and in the following episode from the session, the students are at the reading stage and are deciding which data items are important for their task. Male 1 initiates this activity *(Participants are: M1 = Male 1, M2 = Male 2, F1 = Female 1, F2 = Female 2, and Fac = Facilitator.):*

Who	**Talk / Interaction**	**Encoding**
M1:	right Oberon	INITIATION OF ACTIVITY
M1:	[((goes to drag and create slip but nothing is selected))	PROPOSAL WITH TABLE
 [((all watch as Male 1 tries to drag and create slip)) – CONTRIBUTION		
F2:	((selects a slip)) that's not the right one put it in the trash-	REJECTION and INITIATION OF ACTIVITY and PROPOSAL WITH TABLE
F2:	((moves slip to trash))	

[((all watch as Female 1 selects and moves slip to trash)) - CONTRIBUTION/ACCEPTANCE

M1:	in the trash	CONTRIBUTION
F2:	((continues to select data items and trash them, all continue to watch this activity))	CONTRIBUTION
M2:	((selects slip and moves towards trash)) which one would you like	CLARIFICATION/PROPOSAL WITH TABLE
F2:	that one	ACCEPTANCE
M2:	[((moves selected slip to the centre of the table))	CONTRIBUTION
Fac:	[((Facilitator 2 moves to the group))	INITIATION OF ACTIVITY
Fac:	okay I think because you guys just spent half an hour reading these slides you don't need to read them all again so I'll move you onto the next stage...	
Fac:	((closes this part of the task and moves the group to the next stage))	
Fac:	now we're going to think about what paragraphs you want if you look at the instructions it will tell you how to make a new paragraph	PROPOSAL PROMPTED BY THE FACILITATOR



((read the screen where the instructions are displayed))

This episode demonstrates how the nature of collaboration with and around the table is task orientated - attention to each other's talk and actions is co-ordinated, without any explicit explanations being given. This is reflected in Table 11, where a good number of turns take place, but relatively few proposals i.e. the quality of the interactions is key, rather than just the numbers. Students make use of the appropriate affordances of the table, demonstrating an understanding of the mechanical interactions afforded by the Collaborative Writing Application – i.e. evidence can be selected, read and deleted.

The group however lack a clear focus of the overall task. The facilitator needs to intervene and provide scaffolding for the group to progress, the quality of the collaboration shows little engagement with the Collaborative Writing Application, even though the students actively watch each other and co-ordinate their efforts. Proposals are individual in nature, as they do not build on previous talk, for example, proposals linked to the table are initiated without prior discussion with the group – again the quality of interactions is not expressed fully by the numerical counts in Table 20. Overall, initiations for actions at this stage are superficial, they are not fully engaged with on the group plane.

5.3.2 Session 2 – A Midsummer Night's Dream - Part 2

In this session, the students worked on the same question, based on the Digital Mystery they had completed in the previous session. The session took around 35 minutes.

5.3.2.1 Teacher Interactions

Following on from the previous lesson, the teacher began with a short introduction, again using the whiteboard to record key points. The teacher then maintained the strategy of moving from group to group. As the students were mainly recreating work from the last class at this stage, the teacher moved the class on to the paragraph stage after a few minutes. After around 10 minutes of moving between groups, the teacher moves the class onto the next connecting stage (by addressing the whole class from the front of the room). Again, after 10 minutes, the teacher moves the class onto the insert evidence stage. During this stage, the teacher uses a mixed strategy of moving between groups and taking a more observational perspective, watching the class as a whole without much direct interaction. Finally, the teacher ends the class.

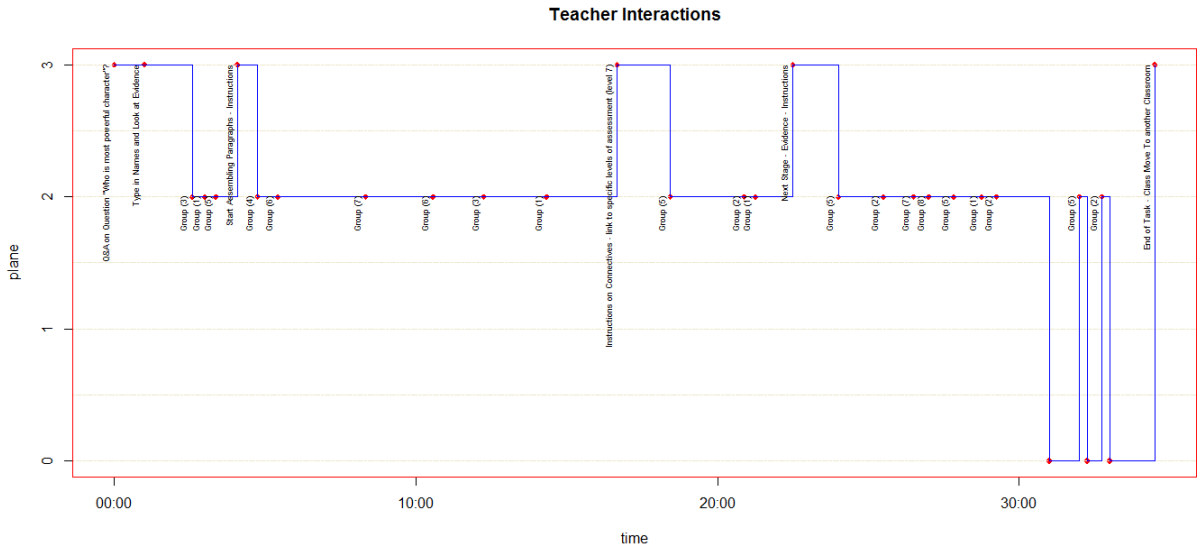


Figure 38: Teacher Interactions 2nd Session

5.3.2.2 Teacher Plans and Reflection

The lesson plan was more realistic (or practical), allowing adequate time for planning. The Digital Mysteries task had been completed previously, allowing more time within the lesson for the collaborative writing task.

With regard to the **Student Progress**, the teacher's reflection noted some students *"had support from adults present".* Feedback from students was also included. Students found working with **The Technology** both *"stressful"* and *"amazing"*, which the teacher interpreted as "*she likes the technique, but isn't yet comfortable".* They also complained about the *"heat"* generated by the tables and their *"sensitivity".* With regard to **The Writing Task** theme, students gave "*good comments about the way CCW assists with the planning and linking of points".* The teacher also noted that:

"There is often too much emphasis on the 'finished product'", however, *"The technology has helped some to appreciate that it's the journey as much as the destination that matters"*

With regard to the written work and **Student Progress**, she noted that usage of evidence was low:

"Some of the plans had very little detail" although *"sometimes well structured".*

She suggested that the "*need to be clear what the objectives are"* might improve this. She identified that there was a need to make stronger links with the material at the Digital Mysteries stage:

"The highest quality essays will evolve from those detailed higher order discussions that are generated at the reading stage".

5.3.2.3 Interaction Logs

Again, interaction logs were recovered from the tables, as can be seen in Figure 39. Table 21 shows what the symbols in the visualisation mean.

In this session, groups were again working on the same topic and question as in the previous session. This meant that the first parts of the task were completed quickly, and were largely a recreation of the work in the previous session. All the groups completed the task and produced plans at the end of the session.

Focussing again on group one; they began by recreating the paragraphs from the previous session, “magical people”, “workers” and adding “courtiers”. They quickly progress onto the connection stage – where they spend some time arranging the paragraphs before actually making connections. The connections they make are not well thought out, using the “built in” connection “however” for all their choices, apart from the final two where they choose to connect the conclusion paragraph with their own connective “overall” and connect the question to the introduction with “it is”. They do try to continue without connecting all the paragraphs, but they correct this. They include data items appropriately for the paragraphs, finding this process easier than the connective stage. Their final action is to amend one of their connectives, the one connecting the conclusion (to “therefore, overall” rather than “overall”).

Across the rest of the groups, a similar pattern occurs, particularly at the start of the session where groups are recreating their previous work. Most groups struggle with the connectives, but go on to find the evidence easier.

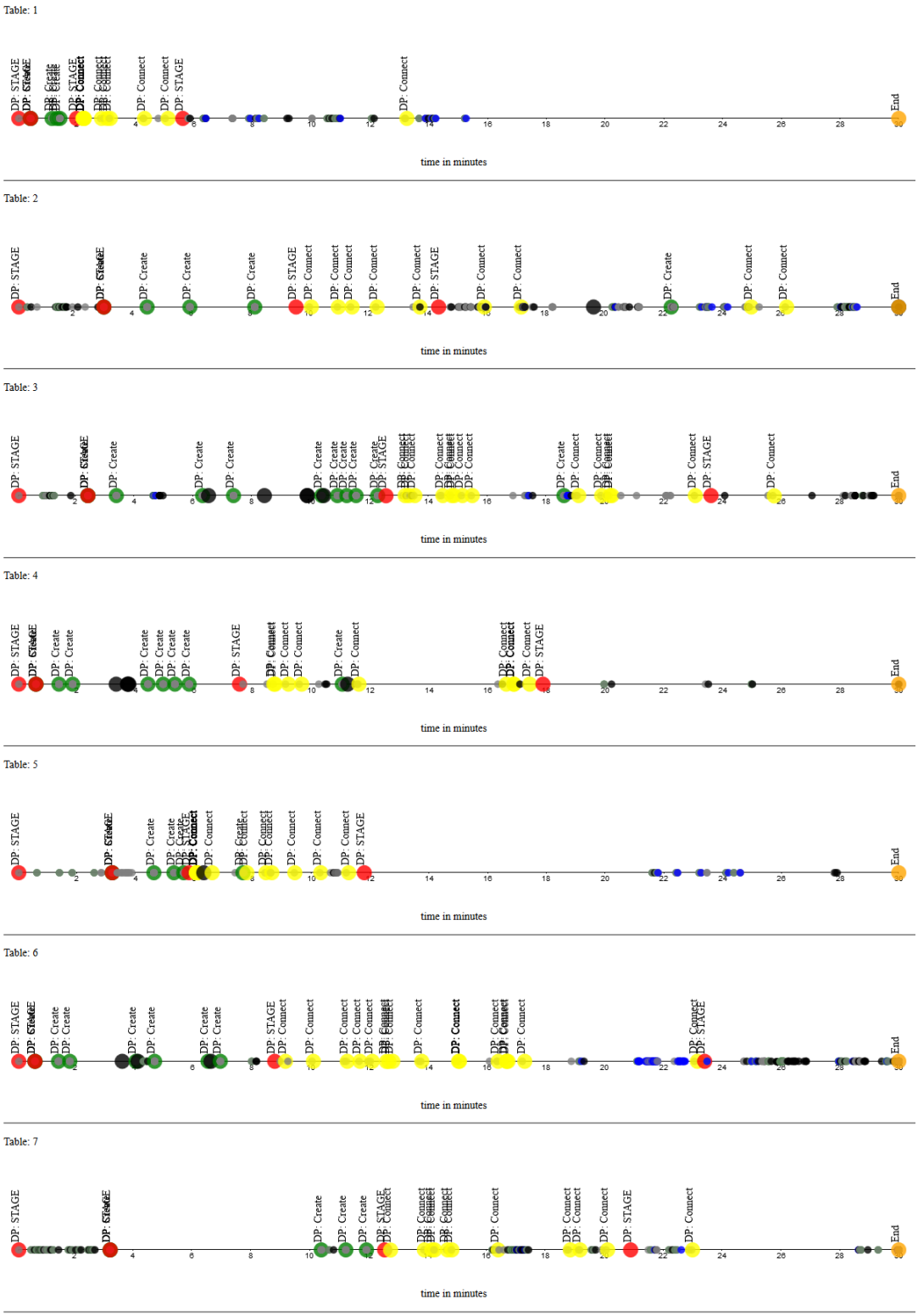


Figure 39: Session 2 - A Midsummer Night's Dream - Part 2

5.3.2.4 Decision Points

After a short recap of the previous session activity by the teacher, the class were prompted to "get back to the stage they were at last session" - i.e. Paragraph connection. This resulted in a quick start to the table-based activity with little

discussion. Again, the interactions around the decision points for table one can be classified:

Decision Point	Classification	Description
Reading Stage End	Facilitator Intervention	Group move onto paragraph stage as per teacher instructions
Create Paragraph	Pre decision	Group create 1st paragraph before deciding name without discussion
Create Paragraph	Pre decision	Group create 2nd paragraph before deciding name without discussion
Create Paragraph	Pre decision	Group create 3rd paragraph before deciding name without discussion
Paragraph Stage End	Facilitator Intervention	Teacher prompts class to move onto next stage (again, recreate previous session structure)
Paragraph Connection	Synchronised	Group discuss how to connect paragraph while making the connection.
Paragraph Connection	Pre decision	Group replicate the previous connection without further discussion (i.e. Mechanically)
Paragraph Connection	Pre decision	Group replicate the previous connection without further discussion (i.e. Mechanically)
Paragraph Connection	Facilitator Intervention	Facilitator points out that connections between paragraphs depend on their relationship, group discuss this further
Attempt Stage End	Synchronised	Group attempt to move onto evidence stage - but one connection is missing.
Paragraph Connection	Synchronised	Group connect and discuss final paragraph connection
Connecting Stage End	Synchronised	Group move onto evidence stage.
Paragraph Connection	Synchronised	Group amend a paragraph connection

5.3.2.5 Single Group Analysis

This episode was chosen to show how the group have moved on from requiring facilitator intervention, but are still not interacting with the table optimally – i.e. their interactions are largely pre decision, i.e. off topic or involving little discussion.

The group quickly (with minimal discussion) got back to the stage they were at in the previous session. There was discussion about connecting the initial paragraphs, however the group were actually talking about the *content* of the paragraph rather than how they connected, and selected a connection arbitrarily. From the log data and video, they repeatedly used the same connection for the remaining paragraphs without discussion.

The group initially wrote about evidence in the paragraphs without including the data items - potentially a more advanced process (if reference to evidence is still included), but once the facilitator reminded them that they could include it directly, they started to use this strategy. There is a noticeable difference in participation when the teacher talks; she sets up the topics (verbally) and the students respond.

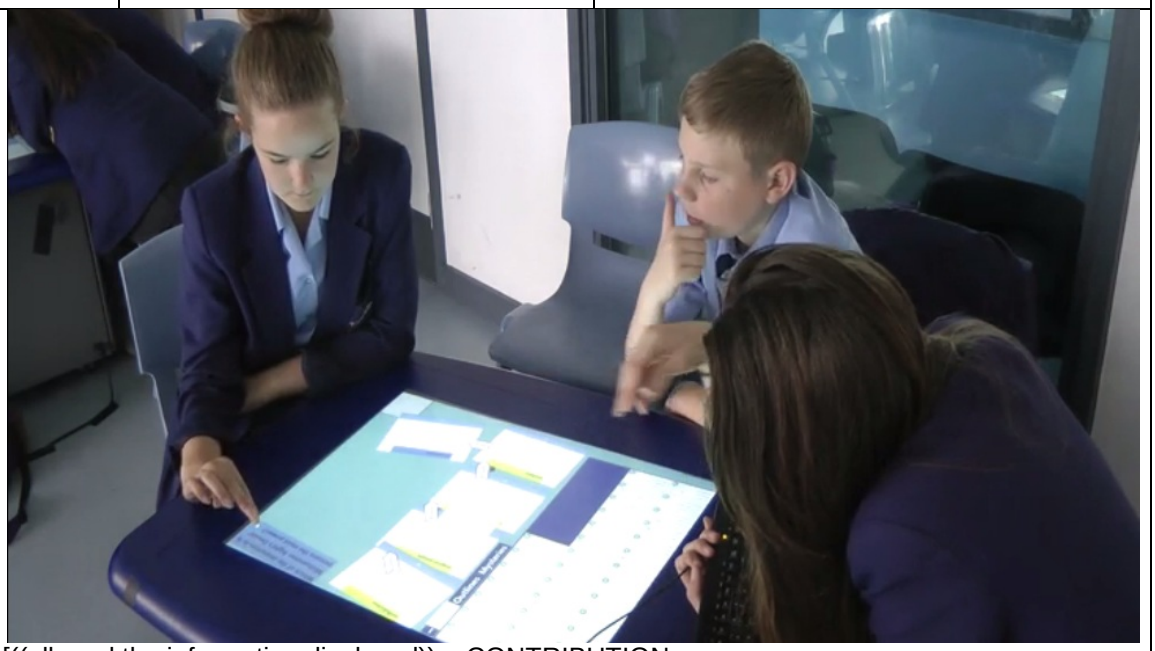
At the end of the task, the teacher asked about their work. The students used the interface to explain how their answer would be constructed. After this, the group adjusted connectives and evidence based on how they had explained their answer to the teacher (and in response to her feedback).

In the following episode, the group are trying to progress to the next stage after connecting some paragraphs. The group begin this episode towards the end of the stage, having already connected most paragraphs.

M1:	next stage ((uses interface to bring up options for move to next stage))	INITIATION OF ACTIVITY & PROPOSAL(1) WITH TABLE
T:	((displays next stage confirm))	CLARIFICATION

((all confirm move to next stage by selecting their individual names)) – ACCEPTANCE

T:	[((displays message to indicate that the activity cannot progress as not enough paragraphs have been selected by the group))	REJECTION/INITIATION OF AN ACTIVITY/ PROPOSAL(1) WITH TABLE



[((all read the information displayed)) – CONTRIBUTION

M1:	[more paragraphs ----- oh then you need to do it	CONTRIBUTION / PROPOSAL 2 WITH GROUP

[((all confirm that they have read the message and move back to the ongoing activity of connecting paragraphs)) – CONTRIBUTION

F1:	((selects previously written text which has not been connected to existing paragraphs and drags to another one))	ACCEPTANCE (2)
T:	((displays the two paragraphs which the students wish to link and connection dialogue)) –	PROPOSAL 3
M1:	((selects connective))	CONTRIBUTION (STILL NOT CONFIRMED)
T:	((connective is added to the displayed text))	CONTRIBUTION

((all re-read the text with the new connective in place)) - CONTRIBUTION		
F1:	most powerful is IS ((shows group where she is referring to))	CLARIFICATION / PROPOSAL 4 WITH GROUP
F2:	((modifies the text in the paragraph))	ACCEPTANCE (4)
G:	((confirm that they agree to all the changes))	ACCEPTANCE (3) / FINALISATION – DECISION MADE!
F1:	((selects next stage))	FINALISATION (ACCEPT) FIRST ACTIVITY - INITIATION OF ACTIVITY

Like the previous session, this episode demonstrates how the nature of collaboration involves the learners displaying joint attention to verbal and non-verbal actions with and around the table. Proposals are offered by students and the table and are highly co-ordinated to achieve specific interactional goals. It is possible to see how from the initiation of the first proposal to 'move to the next stage', collaboration is built into the interaction as proposals are initiated and developed. This episode represents broad patterns of interaction in this second session, and demonstrates an improvement in the quality of collaboration from the first session. The multimodal interaction is focussed on specific goals, and scaffolded more specifically on this occasion by the table. However, similarly to the first session, there is very little verbalisation, for example in how Male 1 selects a connective without consultation. There is also a continuation of similarly individualised action when Male 1 directs the connecting of paragraphs to Female 1 (Female 1 created this paragraph and so is seen to be responsible for connecting).

5.3.3 Session 3 – Greek Mythology

In this session (~30 minutes), the students were tasked with writing a persuasive document answering a question about Greek Mythology, they had completed a Digital Mystery on the topic before the start of the session.

5.3.3.1 Teacher Interactions

In this session, the teacher again begins with an introduction, this time also including an example essay answer from the last session. After this introduction, the teacher divides her time between moving from group to group and taking a more observational role. She spends more time observing than previously,

allowing groups to work unattended for longer. She does not explicitly return to the classroom plane to instigate stage changes, instead allowing groups to progress themselves, or with small prompts to specific groups. At the end of the session, the teacher spends some time with the class expanding the topic and providing assistance for writing up the plans generated during the session.

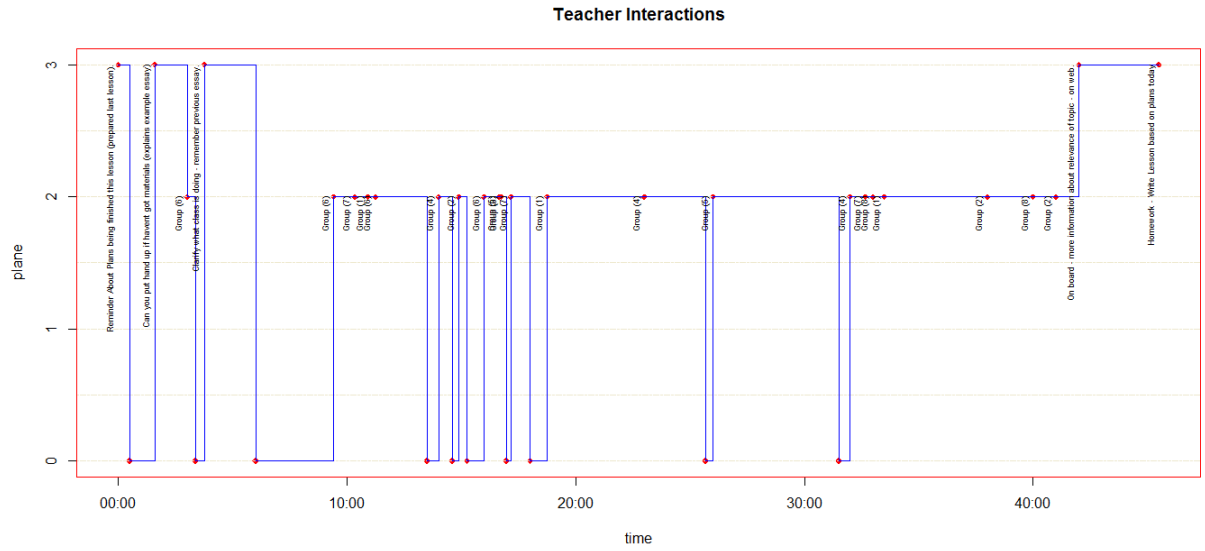


Figure 40: Teacher Interactions Session 3

5.3.3.2 Teacher Plans and Reflection

Following the previous session, in order to improve **Lesson Management**, the teacher planned strategies to encourage greater engagement with the materials:

"They may think of the statements as lacking relevance or importance, but I need to encourage them to think more deeply and analytically about the information",

And, with regard to **Student Progress**,

"This will impact on [key aspects] of the English [year group] reading skills".

However, the teacher also noted that too much intervention might be counter-productive:

"I may need to back off and let them come to their own conclusions".

The teacher noticed a **Lesson Management** improvement with the class; they were *"dealing with the task in a very productive and confident manner – even those who had struggled to focus before"* and the students *"had retained enough knowledge and understanding"* of the Digital Mystery session.

The class are showing some differentiation when it comes to **The Writing Task** – *"Some have seized upon the persuasive aspect but others have still set about writing an explanation/evaluation".* However, the teacher was *"delighted by the level of understanding they have shown and the grouping and evaluation of the evidence. Some have addressed some really sophisticated concepts especially relating to gender and power relationships".*

5.3.3.3 Interaction Logs

Interaction logs were recovered for all the tables except table 3. Table 21 provides a key to the symbols used in the visualisation (Figure 41).

Again all groups completed the task and generated plans. Group one created paragraphs around the different characters in the mystery, re-implementing their strategy from the previous session. They created "Gods", "Goddesses", "Monsters" and "Humans". They then spent some time arranging the paragraphs before moving onto the connecting stage. They employed a different strategy for their connectives, attempting to describe the paragraphs rather than think about how they relate to each other (e.g. "first there's Gods...", "then there's Goddesses...", "Humans also play a part by..." etc.). Although not correct connectives, it shows some understanding how the document would flow – they are providing an opening sentence for the paragraphs. Again, the evidence use is appropriate for the context of the paragraphs, the group consider some evidence and either delete it or use it in a paragraph.

In the class as a whole however, some groups did not include much evidence in the final stage, and others seemed to fill the groups randomly (i.e. groups 3, 5 and 6 in Figure 41 have few evidence insertions (blue circles) and deeper investigation of the logs and plans show them to be somewhat random). The groups that struggled did not have strong on-topic concepts for their

paragraphs, using more generic terms. Despite this, all groups did create a plan by the end of the session, though with the varying merits stated above.

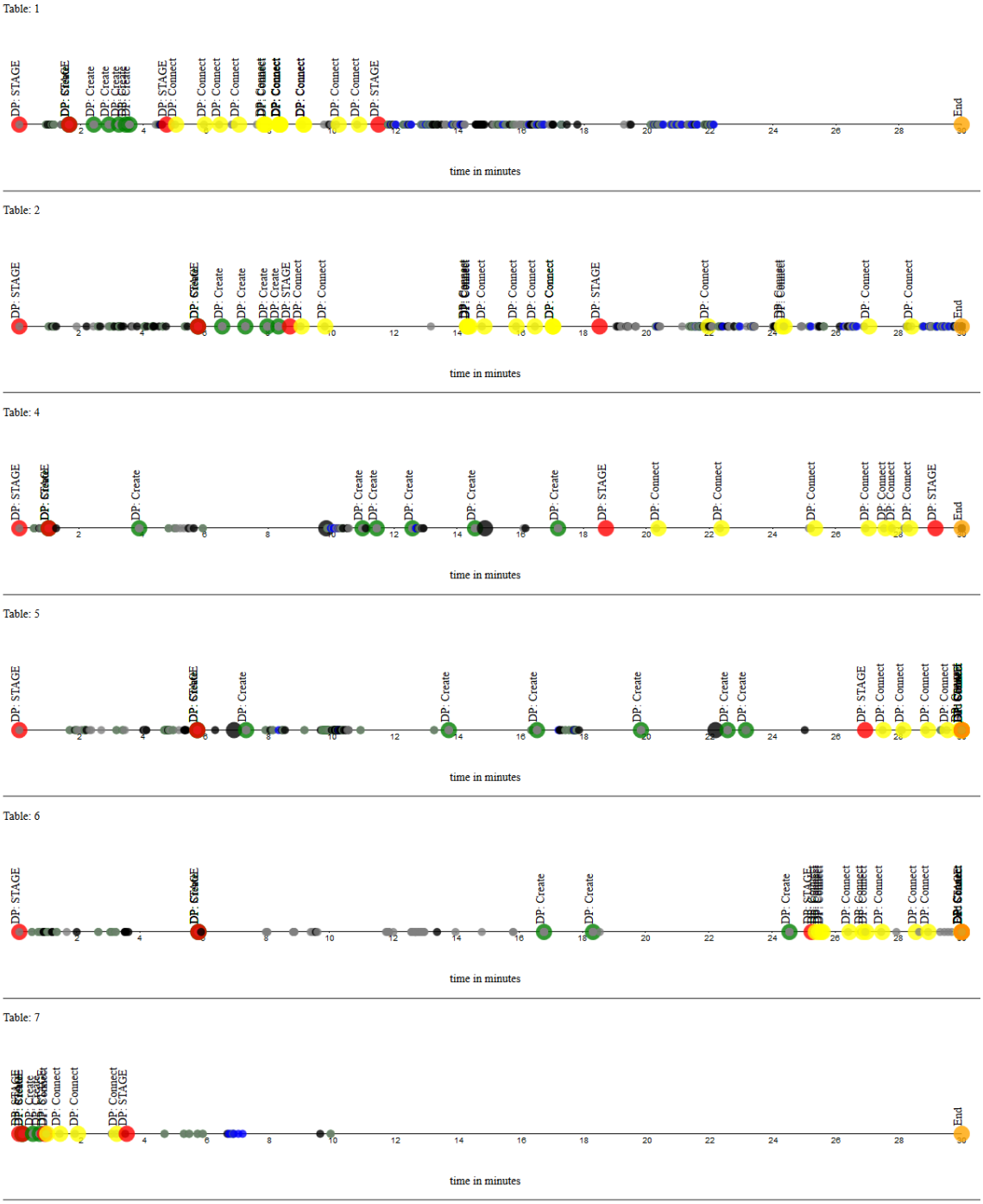


Figure 41: Session 3 - Greek Mythology

5.3.3.4 Decision Points

Again, the decision point interactions were classified (During this stage, there were adjustments to spelling of connections - only new connections have been classified):

Decision Point	Classification	Description
Reading Stage End	Individual Interruption	One Student decides to move on while others are still reading
Create Paragraph	Synchronised	Group create 1st paragraph while discussing name
Create Paragraph	Synchronised	Group create 2nd paragraph while deciding name
Create Paragraph	Synchronised	Group create 3rd paragraph while discussing name
Create Paragraph	Synchronised	Group create 4th paragraph while discussing names
Create Paragraph	Synchronised	Group create 5th paragraph while discussing names
Paragraph Stage End	Pre decision	Group decide to move to next stage while still discussing naming of paragraphs.
Paragraph Connection	Individual Interruption	One Student connects first paragraph while group listens to teacher
Paragraph Connection	Individual Interruption	A different Student connects next paragraph while group are listening to teacher
Paragraph Connection	Pre decision	Group attend to connection process together, but connect before deciding how. (teacher still talking)
Paragraph Connection	Pre decision	Group attend to connection process together, but connect before deciding how. (teacher no longer talking)
Paragraph Connection	Pre decision	Group attend to connection process together, but connect before deciding how.
Attempt Stage End	Synchronised	Group attempt to move onto evidence stage - but one connection is missing.
Paragraph Connection	Pre decision	Group attend to connection process together, but connect before deciding how.
Paragraph	Pre decision	Group attend to connection process together,

Connection		but connect before deciding how.
Connecting Stage End	Synchronised	Group move onto evidence stage.

5.3.3.5 Single Group Analysis

The episodes are chosen to show the increased discussion in the group, along with their interactions with the table becoming more synchronised with their talk.

The group begin by utilising their previous strategy of creating a paragraph for each grouping of evidence. They also referred back to the previous topic (Midsummer Night's Dream) when discussing how to create paragraphs, noticing the relationships between mortals and gods that occur in both topics.

At the start of the connection stage, the group had a short discussion about their overall plan before connecting paragraphs. Initially, they discuss how each paragraph relates to each other, but do not use relational connectives (instead using a listing style – "and then there is X, and then there is Y"). The group attempt to move on, but some paragraphs remain unconnected (prompted by the writing application) – they quickly connect these up without discussion (See Episode below).

At the evidence stage, the group work partially individually, with some discussion of the evidence and where it should go. They try to finish the task, but some paragraphs lack enough evidence (prompted by the writing application), so group members find evidence that broadly fits without discussion. They seem to be focussed on finishing rather than producing a good result, even without external time pressures (no other groups had finished and there was ample time left). They take ideas from previous sessions (i.e. gender roles and power relationships) and apply them to the new material.

The group instigated more proposals before using the table, indicating the writing application scaffolded shared decision making, and more topic development (in terms of turns) after initiations.

In this series of episodes, the group are debating how to create new paragraphs:

F 2:	right monsters ((holds keyboard and prepare to type))	PROPOSAL 1
M 1:	no gods	REJECTION / PROPOSAL 2
M 2:	just put gods	CONTRIBUTION
F 2:	goddesses or gods	CLARIFICATION
M 1:	Gods	CONTRIBUTION
M 2:	Gods and then goddesses.	CONTRIBUTION/ACC
F 2:	((types “gods” as Paragraph as title))	CONTRIBUTION

[((all watch the interface as F 2 types in the text)) – CONTRIBUTION

M 1:	[Just put gods and goddesses.	CONTRIBUTION/REJ-PROPOSAL 3
F 2:	[((confirms Paragraph Creation)) no it’ll work better this way, because it means then we’ll have more excuse to do more writing.	REJECTION(3) & ACCEPTANCE(2)

New Episode - Activity NEW PARAGRAPH

F 1:	((Selects Creates Paragraph))	PROPOSAL 1
F 2:	((types “Goddesses” as Paragraph title))	CONTRIBUTION

((all watch the interface as F 2 types in the text)) – CONTRIBUTION		
M 2:	Yes, it's actually two Ds you can just use the arrow keys.	POSTPONING/PROPOSAL 2
M 1:	I'm sure it's not two Ds.	CONTRIBUTION/REJ
F 2:	It's not two Ds.	CONTRIBUTION/REJ
... Group continue with discussion as to the spelling of goddesses continues over a number of turns until the group confirms the paragraph creation – ACCEPTANCE (1)		
New episode – Activity New Paragraph		
F 1:	((selects creation of new Paragraph))	PROPOSAL 1
F 2:	right what else	CONTRIBUTION
M 1:	demi-gods	CONTRIBUTION
F 2:	[((types demi-gods as Paragraph as title))	CONTRIBUTION
 ((all watch the interface as F 2 types in the text)) CONTRIBUTION		
M 1:	shall we put demi-gods and demi-goddesses in the same thing	CLARIFICATION / PROPOSAL 2
F 2:	yes Courtiers wasn't it no that's in A Midsummer Night's Dream ((confirms Paragraph Creation))	CLARIFICATION / ACCEPTANCE (1)

This series of episodes is representative of multimodal interactional patterns evident throughout the third session. They demonstrate a change in the moment-to-moment development of collaborative interaction from the previous two sessions, seen in the nature of the collaboration and in the quality. Students continue to demonstrate joint attention to the task as they watch the text appearing on the table. Central to the change in quality however is the occurrence of talk before the table is used to carry out actions. The joint focus on paragraph content in the first part of this episode shows how the proposals using the table

develop talk rather than simply initiate it. This indicates a less individualised (i.e. parallel working) use of the table and extended sequences of talk occur which focus on content rather than usability (Episode 1). The final part of this episode, further demonstrates how proposals about content addressed to the whole group take precedent over the table functionality in how the students organise their collaborative efforts with and around the table. In other words, the table is no longer integral to the discussion (i.e. by providing prompts and scaffolding) but is used at the end to *implement* the result of the discussion.

5.3.4 Session 4 – Sport vs. Library

In this session, the students were working on writing a persuasive argument to decide between funding for a library or new sports facilities at the school (~25 minutes). They had previously held a classroom debate (i.e. a classroom exercise not conducted on the tables), including a paper based exercise reading and organising evidence and producing a structure they could use to design their document.

5.3.4.1 Classroom Debate

Unlike the previous sessions where a Digital Mysteries exercise had been completed by the students, the class had instead held a classroom debate on the question. As part of this debate, the students were asked to organise their argument in the debate, using the evidence provided, into a poster.

Interestingly, without further prompting the students used the structures learned from Digital Mysteries and the writing application to represent their arguments. In the example Figure 42, evidence has been colour coded and sorted into groups, and some evidence has already been designated as “red herrings”.

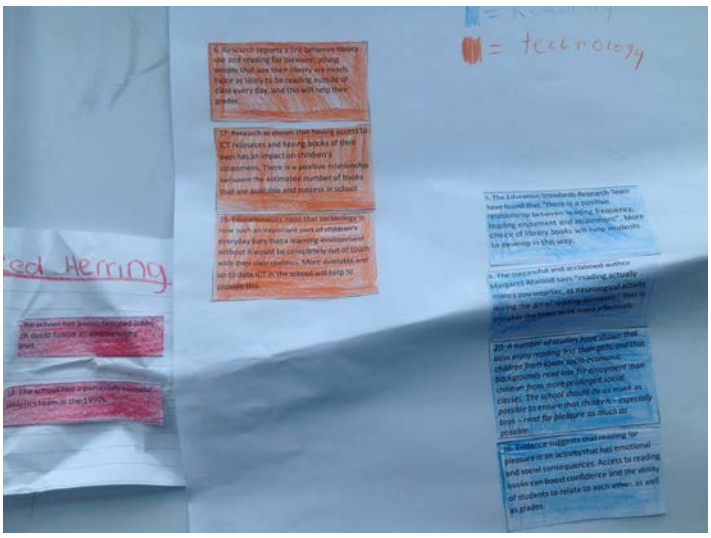


Figure 42: Using Digital Mysteries and Writing Application structures in paper based work.

5.3.4.2 Teacher Interactions

In this final session, after a short introduction the teacher took a largely observational role, only attending to groups who needed assistance. There was an overall impression (from the teacher) that all parties "know what they are doing" and interaction is reduced. Again, the teacher did not instigate stage changes at the class plane. The class proceeds very smoothly, and the final class-plane interaction from the teacher is a simple, short reminder of the homework (writing up their plans).

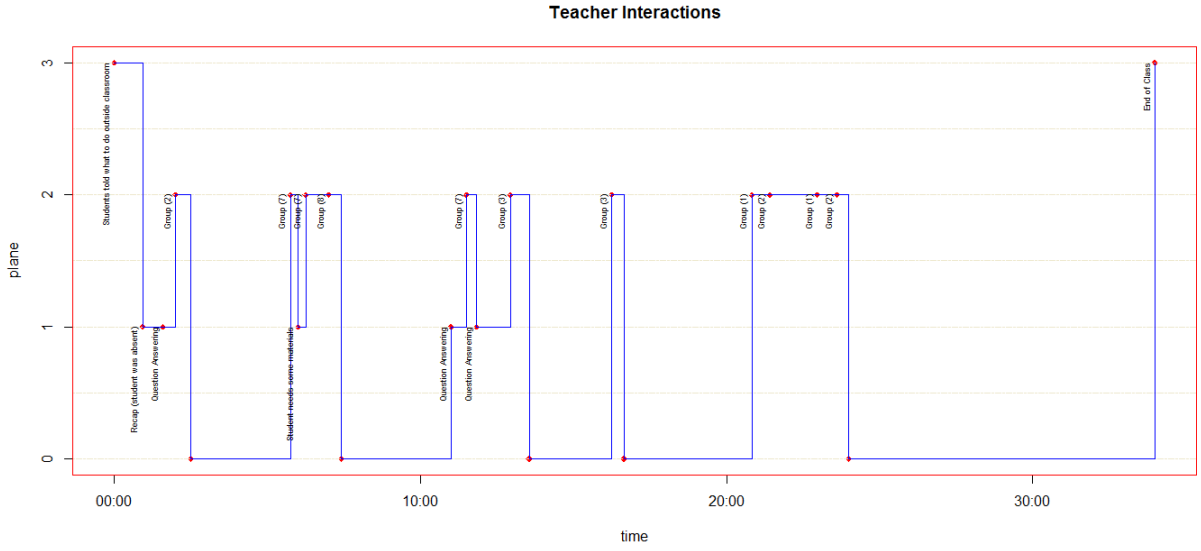


Figure 43: Teacher Interactions Session 4

5.3.4.3 Teacher Plans and Reflection

The teacher noted in her reflection that some of the skills developed during the earlier tabletop sessions might have transferred to the paper-based exercise leading up to this session:

"I noticed that the statements had been very carefully arranged and, in one case, colour coded to show the group's findings".

However, the teacher still had some concerns about differentiation in the class, in particular that *"lower ability groups would hand in work that was mainly produced as copy and paste".* To improve **Student Progress**, the teacher suggests encouraging the students to *"include their own text and make additional points on the plan".*

With regard to **The Writing Task**, the teacher was impressed with *"some very well structured pieces of writing"* and *"while a few have gone for a basic 'for/against/summary' strategy they have done so with some skill and used good expression and explanation".* Students that are more successful *"link paragraphs and shape their arguments in a more sophisticated way"* and on differentiation – *"it would be good if we could find a way to help students use a more sophisticated structure".*

She finished her reflection with suggestions about how **The Technology** could be improved to, in turn, improve **The Writing Task.** Primarily, how differentiation could be achieved by helping the lower performing students:

"…create paragraphs from premade bullet points that are linked by suitable connectives",

"…incorporate comparison between points in paragraphs?",

"…use another visualisation such as a Venn Diagram for example?"

She suggested general improvements to **The Writing Task,** increasing emphasis on persuasive writing, by adding a 'type' to paragraph bullet points:

"…include key elements of persuasive text (i.e. anecdotes, facts, opinions, statistics, expert evidence, emotive language, rhetorical questions etc.)".

5.3.4.4 Interaction Logs

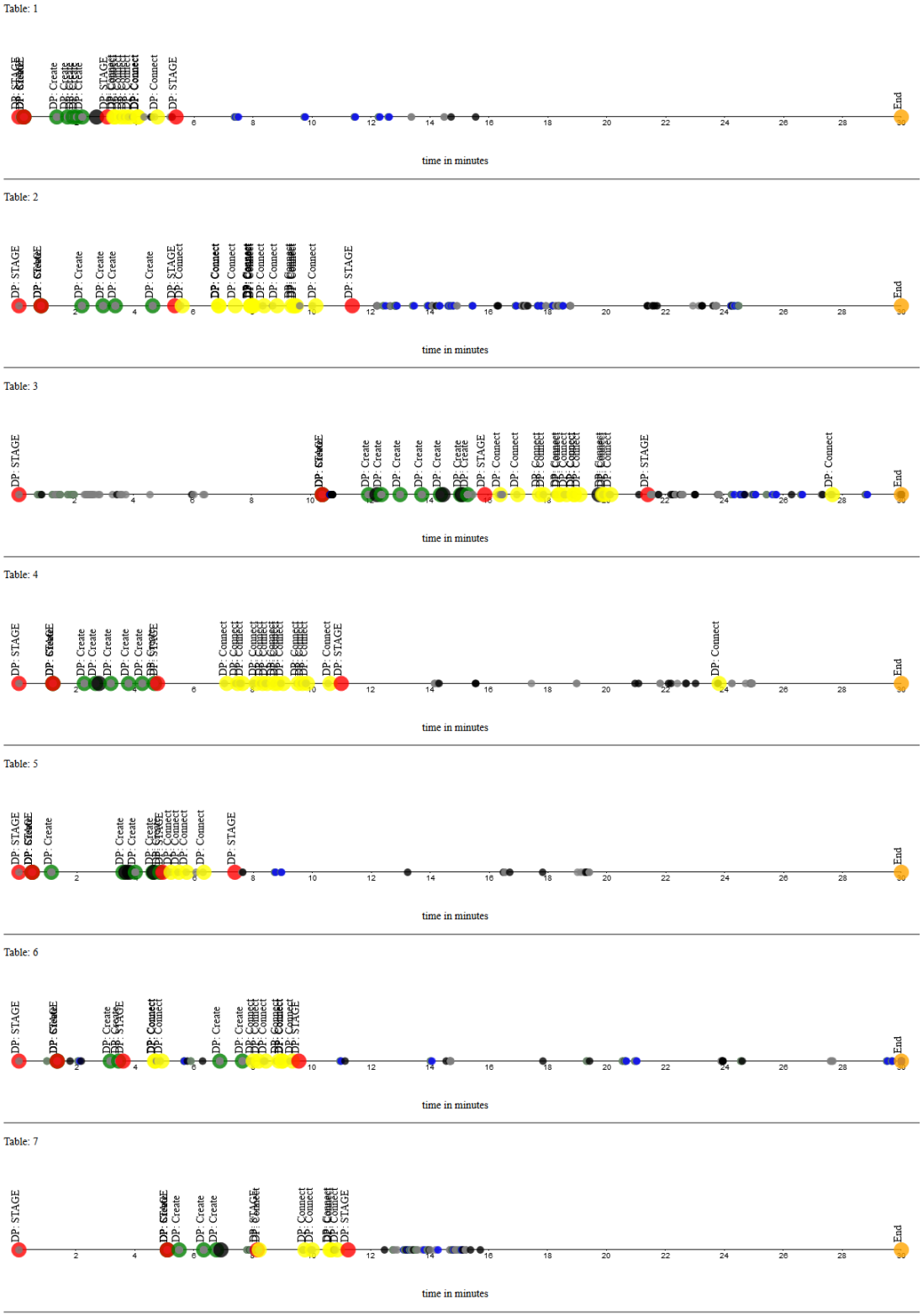


Figure 44: Session 4 - Sports vs. Library

Once again, interaction logs were recovered from the tables (Figure 44), meanings of the symbols are in Table 21. As before, all groups completed the task and created plans. The early part of the session was a transferring of the information generated during their classroom debate into the writing application.

The class as a whole followed a similar pattern as observed with group one (as described in the above section) –i.e. using their previous debate to directly inform their planning activity. Some groups were still unsure about connectives, using the defaults incorrectly, however all groups ended up with useful plans – i.e. plans that contained well named "on topic" paragraphs that in turn contained appropriate evidence and were connected with meaningful connectives.

5.3.4.5 Decision Points

Again, decision point interactions were classified:

Decision Point	**Classification**	**Description**
Reading Stage End	Individual Interruption	Group decide to move on without reading, apart from 1 student who wanted to read more.
Create Paragraph	Post-Decision / Implementation	Group implement decisions made in previous session - already thinking about how to make document
Create Paragraph	Post-Decision / Implementation	Group implement decisions made in previous session - already thinking about how to make document
Create Paragraph	Post-Decision / Implementation	Group implement decisions made in previous session - already thinking about how to make document
Create Paragraph	Post-Decision / Implementation	Group implement decisions made in previous session - already thinking about how to make document
Create Paragraph	Synchronised	Group implement decisions made in previous session - but decide not to include final planned paragraph

Paragraph Stage End	Synchronised	Group decide to move to next stage while talking about connections
Paragraph Connection	Post-Decision / Implementation	Group implement decisions made in previous session - use their own connectives (correctly)
Paragraph Connection	Post-Decision / Implementation	Group implement decisions made in previous session - use their own connectives (correctly)
Paragraph Connection	Post-Decision / Implementation	Group implement decisions made in previous session - use their own connectives (correctly)
Paragraph Connection	Post-Decision / Implementation	Group implement decisions made in previous session - use their own connectives (correctly)
Connecting Stage End	Synchronised	Group move onto evidence stage.

5.3.4.6 Single Group Analysis

This episode is chosen to highlight how the groups' interaction with the table has become more about implementing discussed ideas than as a scaffolding tool.

The group began by transferring the work they had done in the "debate" session, which used the same evidence as was presented in this writing task, into the writing application with little discussion, adding paragraphs and connecting them quickly. Again, before the connection stage they arranged the paragraphs spatially. During connection, as there was a clear dichotomy between positions on the question (i.e. pro sport or pro library), they found it easier to create appropriate connections (however, but etc.). In the include evidence stage, the group discussed the evidence without the table, only using it to implement their decisions.

Much of the discussion during the task was around the use of evidence. Proposals were mainly instigated by students, rather than from the writing application (Table 20). They used some evidence appropriately, but mainly wrote

their own ideas down, after discussion. They used evidence when generating their own ideas, improving on Session 1.

In this episode, the group are adding evidence to a paragraph:

F2:	for the library you could have ((reads notes she has on lap))	PROPOSAL 1
F1 & M1:	((look at a distance at the page of notes that F2 is reading))	CONTRIBUTION
F2:	((Selects Evidence Slip and drags to library paragraph creation dialogue box))	ACCEPTANCE (1)
F1:	((Selects another Slip and drags to library paragraph creation dialogue box))	PROPOSAL 2/ACCEPTANCE (2)
F2:	I knew all of them just put like number three put that in then write something	ACCEPTANCE (2) PROPOSAL 3
M1:	((begins to type into the library paragraph))	CONTRIBUTION /ACCEPTANCE (3)
M2:	like where we can allow children to study hard for upcoming [exams	PROPOSAL 4
M1:	[expand their learning [skills	CONTRIBUTION / PROPOSAL 5
M2:	[expand their knowledge their knowledge on	PROPOSAL 6

((all watch as M1 adds the additional text to the paragraph)) CONTRIBUTION

M1:	on core subjects	PROPOSAL 7

((all nod their heads in agreement)) CONTRIBUTION

F2:	special subjects	PROPOSAL 8
M1:	yes [((types the points into the library paragraph))	ACCEPTANCE (4-8)
M2:	[then put like i.e. English, Maths	PROPOSAL 9
M1:	don't know whether they need special case	CLARIFICATION/REJ (9)
M1:	((Presses enter!!!!!))	FINALISATION

As one of a number of similar episodes observed in the fourth session, this episode demonstrates how the nature of collaboration with and around the table developed over the four sessions. This development has culminated in co-ordinated, productive and high quality collaborative multimodal interaction. The students are actively watching and listening to each other and the episode contains both individualised and collective proposals for action with and around the table. The table is used to both initiate proposals by members of the group and to support the development of verbal proposals linked to content, which is then discussed prior to being added to the collaboratively produced text.

Importantly, this episode shows how high quality collaboration is built up over sessions. It is a merging of a number of behaviours, and not defined by one specific type of multimodal interaction.

5.3.5 Plus, Minus, Improvement Exercise

Plus	
Improved Writing Skills	3
Good Tool for Structuring and Producing Intended Plans (easy to use)	14
Improve Understanding of Topic	4

Improved Efficiency	1
Improved / Easier Over Time – Progression	1
Use skills in other lessons / later in life	1
Good for collaboration	1
Minus	
Sensitivity/lag	3
Boring after a while	1
Table Format (No leg room)	2
Hard to see individual contribution	1
Bugs in CCW	2
Cluttered or Messy - small screen	8
Difficult to understand / keep track of evidence	5
No Response	2
Possible to go wrong (press wrong buttons)	1
Improvement	
Improved Academic Level	3
Aspects of the design (e.g. Connections, Layout, putting data items in paragraphs)	8
The development / background of the research	1
Bugs in CCW	1
Improved Collaboration	6
Helped With Planning / Writing (good tool) - good result	2
Use skills in other lessons / later in life	1
Smoothness of experience	1
different people have different experiences	1
a new way to learn / novelty	1

Table 22: PMI Results

At the end of the study, the students completed a Plus, Minus, Improvement (PMI) exercise as a way of getting feedback on various aspects of the study. In this exercise, each student had to identify a Plus, Minus and Improvement for the task. Table 22 shows a summary of the results. The majority of students identified the usefulness of the writing application as a tool for creating document plans, especially as a way of combining the structure of the document with the evidence in the mystery. The students came to see the writing application as a tool for making plans rather than just a learning task. Some students identified the improvement in their writing skills when using CCW:

"I really improved my writing skills and structure of the text; I believe that this is down to writing up what our paragraphs are going to be about on the machines"

"These tables are really useful when it comes to planning long essays and it helps with improving levels because they can be very fun"

The students also commented on how their academic progress had improved during the study:

"They helped a lot to improve my work from a 5A to a 6A"

"After I used this computer as a plan, my structure level went up 2 sub-levels to a level 7b."

The main criticisms of the study were to do with the technology. Although much improved from the previous study, the sensitivity of the tables was still an issue for some students:

"They are quite sensitive and at first a bit hard to use"

In addition, the interface can become cluttered and messy, causing confusion for some students:

"It was messy so you could easily go off task"

5.4 Discussion

5.4.1 Study Reflection

Overall, the second study was more successful than the first, especially with regard to evaluating the collaborative writing application in the classroom environment. However, without the lessons learned from the first study, many of the problems encountered there would have occurred in this study. The approach was altered in line with those lessons, summarised in section 4.7.2. :

1. **Planning and implementation of deployment** – Understanding that different parties in the study might have different expectations allowed for a more successful planning process. Involving the school and especially the teacher early in the process allowed all sides to

communicate their goals for the study, and how it could benefit all parties.

2. **Improved software design** – This early discussion involving the school and the teacher allowed for input into CCW design that was not possible in the previous study – and having the teacher think about how the design could work led to more understanding about how the technology could be used in the classroom.
3. **Teachers gaining experience in using the technology** – Involvement in the design of the software gave the teacher an understanding of the goals of the study that would not be possible with an ordinary "training" scenario.
4. **Understanding the limitations of the technology** – Understanding what the technology *cannot* do is just as crucial as understanding the aims and functionality. The fact that the technology does not orchestrate the class, regulate progress (with regard to time) and the limitations of the scaffolding (i.e. the teacher still needs to monitor and scaffold groups) are all aspects that were not communicated adequately in the first study.
5. **Give teachers ownership of the technology** – Ultimately, if the technology is to be successful, the teacher must see the benefits for their own teaching agenda. Incorporating the technology into lesson plans, and assigning specific teaching outcomes to sessions using the technology have a positive impact on making the technology a useful teaching tool as well as a useful learning tool.
6. **Reliable technology** – In studies of this kind is that technology is used that is cutting edge or even developmental. In the first study, the reliability had an impact on student engagement. For the second study, the manufacturers re-fit of the digital tables largely mitigated these problems (though not 100%), and this led to a smoother, more reliable study. However, it is also important that students and teachers are aware of the "cutting edge" nature of the technology, so that their expectations might be appropriate. In this second study, more effort was

made in approaching the class as co-researchers to foster a sense of partnership in the study.

7. **Give students' work purpose** – In the first study, it was made clear to the students that their work on the digital tables would not be assessed and would not go towards their marks for the class. Given that this first school had a much more assessment-focussed culture, this proved to be a mistake, as the students were less motivated to engage. For the second study, it was agreed with the teacher (and the school) that students would get appropriate feedback (i.e. marking of work but also in-class discussion, model answers, peer review etc.). The second school had a more skills focused culture, and this feedback was a normal factor in lessons. Coupled with the specific goals laid out by the teacher for each lesson based on her lesson plan and attainment targets, the students were more engaged, and generally seemed to enjoy the process far more.

5.4.2 Evaluating the Collaborative Writing Application

Both the teacher and the students had a changing relationship with the technology, and in particular the collaborative writing application. The teacher reflected that incorporating the technology into her classroom began as a challenge, and integrating the writing application into lessons was difficult. Her initial focus was on the technology, and how (or if) it would work for her teaching goals. Over the sessions, the concerns of the teacher moved from focusing on the *technology* to focusing on the *task.* The teacher began to see the technology as a useful tool for *her,* and what *she* wanted to achieve with the students. By the end of the study, the teacher's feedback was almost entirely *task* focused, concentrating on how the task performed as a teaching mechanism. She also began making suggestions about improving the task to fit better with the requirements of persuasive writing (alternative visualisations, themes for paragraph outline points etc.). A key potential area for improvement was differentiation and flexibility, both as part of lesson planning and in real time during the lessons. The students' relationship with the writing application centred on proposals, and their talk and interactions with the collaborative writing application developed across the sessions:

5.4.2.1 Sessions 1 & 2:

Initially, the writing application is not central to the students' talk or to their activity, (any talk about the technology is focused on hardware). At this stage, facilitators were the prime source of proposals and the writing application is not fulfilling its role as a "provider of expertise" that provides scaffolding to the task. Although it produced proposals, they were attended to less (compared to later sessions). The writing application proposals were used superficially. Decision points do not lead to discussion and are generated and dismissed on an individual basis. It is almost as if the technology is being used on a turn-by-turn basis and not as a collaborative tool.

5.4.2.2 Session 3:

The group themselves began offering proposals, which were discussed and the collaborative writing application is used to facilitate the transition of ideas to writing as a collaborative effort. The writing application provided proposals (through decision points etc.) that were attended to by the students, as evidenced by the amount of discourse turn-taking around these proposals increasing. In other words, the decision points are fulfilling their purpose of instigating discussion. The table could be seen to fade in prominence in the collaborative process [141], instead of being a source of proposals and prompting discussion through decision points it is becoming a "tool" for facilitating the recording of shared decision making, i.e. the students are interacting with each other more than the table.

5.4.2.3 Session 4:

Members of the group readily offer proposals for discussion among the group. The collaborative writing application takes on a more background role; as a facilitator of the transition of the groups' ideas to writing as a collaborative effort. Students turn to face each other as each takes their turn to write a paragraph and make further proposals overseen by the group. The writing application approaches becoming a writing *tool* in the sense that it implements the intentions of the group, as opposed to simply a learning application. Proposals come from the students and the writing application is simply used to fulfil decisions made collaboratively. In this session, some of the writing application's design elements (i.e. prompting for

group agreement) actually begin to hinder students' collaboration by providing unrequired scaffolding.

5.4.3 Impact of the Writing Application

The previous section discussed how collaboration takes place and the qualities of this collaboration, but how do these relate to the *design* of the writing application and its integration into classroom practice?

5.4.3.1 Decision Points

The students' discussion across the sessions were subtly influenced by the collaborative writing application, as the structure of the task (i.e. stages) became how the students structured their discussion. Initially, discussion focused mainly on the technology rather than the task. "On topic" talk was prompted by facilitators (i.e. the teacher and observing researchers). By the 3rd session, talk moved onto the structural requirements of the task. Here, proposals were mainly instigated by the collaborative writing application (in the form of decision points) and were attended to by students in their discussion. In the final session, student discussion focused on the content of the writing, the evidence and how it contributed to forming their argument. This discussion was prompted by proposals from the group themselves.

5.4.3.2 Paragraphs

Initially, naming of paragraphs was quite generic; students were not focused on the content of the task. After facilitator prompting, the group used this better strategy across all the sessions. The teacher incorporated talking about this strategy to the class into her plans for future sessions. Discourse around naming led to conversation about the meaning of the topic as evidenced in Session 4.

5.4.3.3 Connecting Paragraphs

During the connective stage, students' discussion reflected on previous sessions where similar relationships and themes had taken place (e.g. between mortals and gods in both A Midsummer Night's Dream and Greek mythology, or the role of women in each of the topics). This showed that concepts outside of the task at hand (i.e. writing) were being considered by the students. The teacher noticed this

transfer of learning in her reflection. She indicated that this was a positive effect, to be encouraged in future sessions.

5.4.3.4 Evidence

A persuasive argument requires a good understanding of evidence. Students acquire an understanding of this through their use of evidence in structuring paragraphs, and in the final writing. The group began writing their own outline points rather than using the evidence directly, but without relating them to the evidence provided. Across the class, evidence was being used haphazardly, in response, the teacher amended her lesson plan for further sessions to include an emphasis on the importance of evidence, and promote a learning context around the technology - an example of the teacher and technology working together. By session 3, the group used the provided evidence exclusively, without writing about their own ideas. This was partially in response to the teacher's intervention. Finally, the group wrote their own ideas again, but this time with an understanding of the evidence, picking out key data items to augment and improve their argument.

5.4.4 Parallel vs Collaborative Working

Initially, as with the previous study, the design of CCW 1.2 "forcing" collaboration through decision points was jarring to the students (potentially breaking concentration), as can be seen from the "individual interruptions" occurring in earlier sessions. However, as the study progressed and the use of CCW changed, the students began to switch to collaborative working more naturally, indeed pre-empting CCW towards the end. However, there is scope for improvement in this designed interaction, in particular its binary nature (either collaborate OR parallel), unilaterality (not a joint decision on when to collaborate) and immediacy (no warning given, and no chance to "just finish one thing" before freezing).

5.5 Conclusion

This study continued the work to address the research objectives concerned with adapting the collaborative learning design to the reality of the classroom and examine the engagement process in order to maximise the likelihood of a successful deployment.

The study consisted of an "in the wild" evaluation of the Collocated Collaborative writing application on multiple digital tabletops. The study aims to evaluate CCW in terms of collaborative behaviours (rather than to improvements in the writing task), when situated in the classroom. Based on lessons learned from the previous study, the data collection strategy and the approach taken when engaging with the school were changed.

Adapting the approach taken when engaging with the school, by establishing expectations and limitations between the school, teacher, students and academics, a stable environment was created where evaluation of CCW could take place without being dominated by the issues identified in the previous study.

The group-level data (video and integrated with interaction logs) followed a single group throughout the study, to give a better impression of progress and changing use of CCW. To get a wider classroom context it included a classroom camera, interaction logs, teacher plans and teacher reflections which gave an overview of the integration of the technology in lessons.

The analysis shows the changes for both the learners and the teacher throughout the study: the teacher begins tentatively, but eventually incorporates the technology into her armoury of teaching tools – even suggesting task-orientated improvements. These include the labelling of specific paragraphs or arguments in the plans using common elements of persuasive texts, such as anecdotes; facts; opinions; statistics; expert evidence; emotive language; rhetorical questions etc. The teacher also suggested adding extra graphical tools to CCW, specifically to allow the direct comparison of pieces of evidence, such as a Venn diagram tool, or "weighing scales".

The students' interaction with CCW progresses from relying solely on facilitator proposals, through using the writing application's scaffolding, to the point where the writing application is a writing tool and the scaffolding actually hinders implementation of ideas. It is also clear that in comparison with the first study, the teacher's relationship with the technology, how and when they scaffold learning around it, and how it is integrated into lesson plans is integral to how students adopt it. The students need their work to have value in order to engage, and this is provided by the teacher.

Overall the study shows that the design of CCW (using decision points to "force" collaboration, using stages to regulate progress etc.) does encourage collaborative behaviour, and that this behaviour changes in quality over the course of the study, to a point where the scaffolding provided by CCW is not required. This suggests that the design recommendations from the initial design phase (chapter 3) are indeed applicable for making a non-collaborative learning task collaborative. The study also shows that if a teacher sees CCW as a benefit to their own agenda, then it can be integrated into their plans and potentially have a longer-term learning impact (depending on future studies in this area).

However, CCW did not perform perfectly, and without this longer term study the impact on learning is uncertain. Although the need for scaffolding reduced, CCW did not detect this and did not adapt to the requirements of the learners. This could also have an impact on differentiation in the classroom, where the task may need to be adjusted for high or low performing students. The mechanism for encouraging collaboration may also be too simplistic, and there is potential future work in investigating different approaches to the decision-point concept. These and other potential improvements are discussed further in chapter 6.

Chapter 6

Discussion

6.1 Overview

The focus of this research is outlined in the introduction (Chapter 1) of this thesis. It is characterised by the research questions: *"How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?"* and *"How can a small group based collaborative learning task be scaled up to an "in the wild" classroom multi-group deployment?"*. To answer the first question, the research aims to build a design for a learning application for Persuasive Extended Writing composition grounded in an understanding of the benefits of collaborative learning and leveraging the collaborative technology afforded by digital tabletops. This can be summed up by satisfying the specific research objectives:

- To identify the benefits of collaborative learning:
  - The literature review (Chapter 2) establishes that the concept of collaborative learning and the potential benefits are readily understood.
- To identify collaborative design elements and technologies utilised in existing work – specifically in the co-located, face-to-face collaborative learning context.
  - The literature review goes on to examine face-to-face collaborative technologies (such as digital tabletops) and collaborative design elements (such as visuospatial representation) that can be exploited in co-located, collaborative application design.
- To investigate a suitable "non-collaborative" task (i.e. writing composition) in order to provide a candidate for the design.
  - The examination of the literature in Chapter 2 identifies learning Persuasive Extended Writing as a suitably individual and complex task to use as a basis for the design.

- To create a mapping for the task to design elements that could be used in a collaborative learning way (as indicated by previous work).
    - Utilising the literature explored in Chapter 2, Chapter 3 begins a design process based on suitable visuospatial mapping of task elements into the interaction space.
- To produce and test a candidate design to ascertain if designed-for collaborative behaviours occur.
    - Chapter 3 presents a learner centred design built upon the knowledge gained from the literature as a candidate application, and this design is refined through two "in the wild" classroom studies (Chapters 4 and 5).
- To produce guidelines that may be utilised in the general case – i.e. for other "non-collaborative" tasks.
    - Chapter 3 concludes with a set of recommendations that can be used in the general case where a non-collaborative learning task can be adapted using visuospatial metaphors into a collaborative one.

The work addresses the second question by deploying CCW within two classrooms over the course of two studies. This process was about understanding how to design the software and the context around the software to enable use "in the wild", i.e. the classroom. In doing so, the work goes towards satisfying the following research objectives:

- To adapt the collaborative learning design to the reality of the classroom and available technology, producing a realistic candidate application.
    - During both Studies (Chapters 4 and 5) the design was refined to meet the needs of both Students and the Teacher(s).
- To examine the engagement process with schools and teachers in order to maximise the likelihood of a successful deployment.
    - The first study (Chapter 4) is dominated by issues around the reality of a classroom deployment and the need to understand and communicate the expectations of all parties

(i.e. the school, teacher, students and academics). Lessons learned from this process informed the second study (Chapter 5), allowing for a more thorough evaluation of CCW (version 1.2) in the classroom context.

- To observe CCW in action over a number of sessions in order to analyse both the engagement process and the collaborative performance of CCW.
    - The second study in particular (Chapter 5) allowed for an ongoing analysis of CCW in the classroom context, from both the students and teachers point of view. The analysis revealed a changing attitude to CCW that showed adoption by the teacher and the students into their practice.

6.1.1 Utilising Visuospatial Interaction for Collaboration

The potential advantages of collaborative learning are explored in the literature outlined in the second chapter of this thesis (Section 2.3). In essence, collaborative learning utilises peers as a resource in the learning process. In particular, where peers' expertise differs across the group, then the communication of this expertise potentially enriches the group as a whole. This communication process, characterised by Vygotsky [132] as an externalising/internalising of cognitive processes across the group is one area where technology can be leveraged.

In the case of this research, the learning task is composing Persuasive Extended Writing, a writing task seen as particularly difficult to learn [39,43,50] which is normally learnt on an individual basis. Section 2.1.1 and section 2.2 provide an overview of the task and the learning techniques. The task is suitably difficult for learners to merit exploration – in particular how to take advantage of collaborative learning techniques.

Focusing on extending communication as a collaborative tool, the research examined the use of visuospatial interaction techniques (Section 2.3.4) to enable collaborators to represent their thinking in a form that their peers could examine and manipulate and, ultimately, internalise. This concept suggests the use of specific technologies, in particular the shared space, face-to-face collaborative environment afforded by digital tabletops (Section 2.5). Examining Digital

Tabletop applications with similar goals (Sections 2.5 and 2.6) informed an initial design for the collocated collaborative writing application.

The initial design process, outlined in the third chapter, took a learner centred design approach. The design was refined over three iterations involving three groups of learners, both to assess if the interface was intuitive (i.e. understandable) and if it was generating appropriate visuospatial representations (i.e. useful for collaboration during the task). This process occurred in the lab, with enthusiastic volunteers, under the supervision of researchers rather than teaching staff. The culmination of this process was a prototype application ready to be tested in a real "in the wild" classroom environment, where the context of the learning is just as important as the activity itself.

6.1.2 Extending Digital Tabletop Learning to the Classroom

Most studies involving digital tabletops concentrate on utilising a single table (i.e. one group at a time) [52,60,103,105], or are at least conducted in a controlled environment where facilitators are predominantly researchers involved in the study [34,44,46]. While successful in establishing the benefits of digital tabletops for groups, and going some way to emulating a classroom-type environment, these studies fall short of fully "in the wild" study. They lack the pressures of situating a deployment in an actual classroom, and they lack connection with the actual teachers who would be theoretically using the technology on a day-to-day basis once the researchers are gone. It is difficult to make the statement that any study is totally in the wild however, as any intervention outside of normal school activity necessitates a change of behaviour of the students and the teacher. The aim is to minimise that effect to discover the underlying impact of the intervention.

This work attempts to go further than previous studies to create a truly "in the wild" setting. To accomplish this, two studies were conducted. Chapter 4 outlines the first of these studies. The plan was to deploy technology into an actual classroom in a school, to have sessions facilitated by the students usual teachers and based on content that the teachers themselves had devised from the students curriculum. The chapter provides detail of the challenges involved with implementing the study. These included the practical and logistical problems encountered, such as classrooms being unavailable, having to setup and dismantle

between each session, problems with the technology etc. The chapter also discusses some underlying problems that occurred due to the differing expectations that the various parties (students, teachers and researchers) had for the study. These findings are taken forward into a second study.

Chapter 5 describes this second study. The lessons learned from the previous study inform the planning and execution of this study. The first change was to attempt to manage the expectations of the study from the beginning. The teacher was involved from the very start of the study planning stage, and findings from the previous study were openly shared. This included limitations of the technology; what the technology could not do (and was not designed to do) were as important as the functionality. The teacher also explicitly included the technology in her lesson plans and provided detailed feedback after each session. This collaborative preparation allowed the study to progress more smoothly, and allowed for a focus on findings that were closely linked to the learning activity and the teacher's ownership of the technology rather than the challenges of a classroom deployment.

6.2 Results and Contribution

The work described in this thesis is centred on answering two main research questions. Firstly, "*How can applications be designed for learning tasks that are usually non-collaborative such that they exploit the benefits of collaborative learning?*" and secondly "*How can a small group based collaborative learning task be scaled up to an 'in the wild' classroom multi-group deployment?*". In essence, answering the first question is an investigation into *designing for collaboration* while answering the second is an enquiry into *designing for the classroom*.

6.2.1 Designing for Collaboration

The learner-centred design outlined in Chapter 3 investigated how a collaborative learning application could be constructed from a non-collaborative task, such as learning composition of Extended Writing documents. Learning Extended Writing is a suitable task for this initial design, as it is usually undertook individually, and is notoriously difficult [38,39,43,50,51,86]. The difficulty stems from understanding the structure, specialist vocabulary and additional requirements of creating an

Extended Writing document such as planning, revising, use of external material (i.e. evidence) and writing for an audience [9,39,65]. Writing frames provides a set of genres for Extended Writing, and a framework for learning how to compose these documents [15,76,135]. However, the method is geared towards individual learners.

Previous work on using technology to facilitate collaborative writing has concentrated on tools for remote authors to write together [4,37]. This kind of technology is mainly concerned with allowing co-authors to know which parts of the document they are working on or are responsible for (e.g. through colour highlighting). This is not necessary if users are collocated, as would be the case for learners working in a group. In addition, these applications are not geared towards learning how to write, but are designed for expert authors.

Collaborative learning applications for learning tasks that are already collaborative in nature already exist [60,103,105], often exploiting the collaborative affordances of digital tabletops [26,63]. Collaborative learning applications for improving literacy collaboratively tend to focus on speech or storytelling rather than Extended Writing [2,19,111]. This work is designed initially to provide a collaborative writing application where students can learn to compose Extended Writing documents on the digital tabletop. The lessons learned from this design process are then generalised, so that other individual learning tasks can be transformed in order to exploit the benefits of collaborative learning.

The process involved designing suitable visuospatial elements to represent parts of the task (i.e. users are able to represent their thinking in a task focused way, depending on the goal and requirements of the specific task), and utilising them in a shared interactive space digital tabletop. This allows learners to make representations of their thinking, a key collaborative learning concept [67,89,132,143] that provides an extra medium for collaborative communication. The collaborative learning application can also regulate progress through the task, by separating the task into suitable stages and providing scaffolding [140,141] at suitable points (i.e. when the criteria for progression have not been met). Generalising this process generates three key design guidelines that go towards making a non-collaborative learning task into a collaborative learning one.

6.2.1.1 Task Focused Visuospatial Elements

Dividing the task into appropriate visuospatial sub-tasks affords collaboration and increases awareness of action. It affords externalisation of thinking and appropriation [31]. Sharing a concept of a task and the processes involved is part of Distributed Cognition [47,89,107]. Choosing the visuospatial elements is a design challenge – they should be based on the goals of the activity. In the Extended Writing example, there were many possible candidates for visuospatial elements (paragraphs, connectives, sentences, words, evidence etc.) The intention of the task, to form persuasive arguments from the evidence to plan the structure of a document, determined the elements chosen (paragraphs, connectives and evidence) while omitting elements concerned with language, grammar, sentence structure, etc. This allowed for a focused task that was not bloated with unnecessary visuospatial elements that were not task focused. In general, choosing a streamlined set of visuospatial elements that are strictly concerned with the task goals will allow representations and thinking that is also focused on the task goals. It allows for representations of thinking that are on-task, without the distraction of extraneous or distracting visuospatial elements.

6.2.1.2 Structured Interaction

Designing the structure of the task requires an understanding of the key processes required to complete the task [60]. An initial open structure, with no separate stages, allows for the observation of shortcuts or incorrect processes by the learners. The structure of the task should reflect the goals of the task, i.e. all required actions should be performed, but should also reflect the areas where learners that struggle try to skip, or do not attach appropriate importance to. These neglected elements that are not being used as planned can be redesigned, combined, omitted (if not important) or explicitly enforced (if they are important for the overall task). Adding structure by splitting the task into stages allows for suitable decision points and scaffolding to be injected [60]. It also ensures that the required focus and effort is given to key activities. Over-use of stages should be avoided, as they can lengthen a task unnecessarily. In the Extended Writing task, the use of stages changed even after the initial design process. In the second study, the order of the stages was altered to more closely fit the agenda of the teacher

involved. This shows another benefit of stages – flexibility. A teacher can rearrange or omit stages depending on the particular needs of the learners, for example as a method of differentiation across a mixed ability class.

6.2.1.3 Decisions Regulate Collaboration

Collaborative tasks (of significant length) may well have periods of high collaboration (i.e. all collaborators are working together), such as discussion, but also periods of parallel working, where collaborators work on part of the task individually (see Figure 13 in Section 3.3.1). This pattern of collaborative and parallel working is observed during the studies and became evident in the design phase (Section 3.3.1). The design of a Collaborative Learning application should allow for both modes of working. Left unregulated, learners will sometimes resort to parallel working for the full duration of the task, making decisions without group consultation that effect the group's work as a whole. It is important therefore that there are mechanisms in place to bring the group back to discussion, in order to form consensus about important decisions, but also to provide a medium to share expertise and thinking with the group. Decision Points provide that mechanism. During a Decision Point, all parallel work is suspended to emphasise the importance of the task, and progress can only continue once users have discussed the decision and agreed to continue (consensus). This does not of course preclude discussion during other parts of the task, but it does at least enforce a consensus building discussion at key points in the task.

6.2.1.4 Risks of "Forced" Parallel vs Collaborative Working

This suspension of parallel working does have risks, particularly in the way it was implemented during the studies. The action is binary, i.e. everything is suspended or parallel with no intermediate states. It is also immediate, with no warning mechanism, which could potentially interrupt concentration of students. It is also unilateral, a single user can decide to suspend activity without any mechanism for others to agree, or override.

During the first study (Chapter 4), although there was insufficient data to analyse CCW fully, it did occur that some students were disrupted by the decision point mechanism – they would have preferred to "work on their own bit" of the task. It can be argued that this was a general preference to work individually or

cooperatively rather than collaboratively, however it could be an issue with interrupting individual concentration or flow.

In the second study (Chapter 5), the Decision Point mechanism did have some minor issues in this regard with the group that was filmed. The group initially were interrupting each other's work, however, they adapted their behaviour and eventually began discussing their decisions before the suspension took place, instead using the Decision Point to *implement* their ideas rather than as a *cue* to collaborate. Although the mechanism was not perfect, it did bring the group together and prompt discussion – which was the goal of the design. Section 6.4.2.1 discusses improvements to the mechanism that might alleviate some of the downsides.

6.2.2 Designing for the Classroom

In the first study, described in Chapter 4, extending the collaborative writing application had to overcome a number of challenges that made evaluation of the collaborative writing application untenable. Practical challenges, such as access to classrooms, setting up and dismantling equipment and reliability of technology coincided with challenges of expectation, where the different parties involved – students, teachers and academics – had differing expectations of the technology's capabilities and the responsibilities during the study. Solutions such as those offered by Kharrufa et al. [58,59] largely concentrate on the technology – improvements to the design and incorporation of orchestration technology may eventually be beneficial, but this only forms a partial solution and fails to address these more fundamental concerns, especially the expectations of the various stakeholders. These concerns were summarised as a number of issues, the addressing of which formed the basis of the second study (described in Chapter 5), which ultimately led to a successful evaluation of CCW, and could provide a model for longer-term integration of such technology in a school as a whole.

6.2.2.1 How Findings from the First Study Improved the Second Study

The issues raised in the first study led to an unsatisfactory study in terms of evaluating the collaborative writing application; however, knowledge of the issues encountered in the first study allowed the second study to be more successful. So how did the studies differ with regard to the issues? Looking at each issue

independently and comparing the differences between the studies shows the value of the first study in making the second more successful, and points the way to future long-term school-wide adoption of such technology. There is some correlation with the orchestration model presented by Dillenbourg and Jermann [27], in particular the theme of *integration* – *"…the combination, within a consistent scenario of individual, small group and class-wide activities, as well as activities beyond the class."* However, there are areas of the model that remain unaddressed or untested (such as designing for teachers of all abilities) directly by the technology where a specific orchestration technology (as suggested by Kharrufa et al. [58,59]) may be desirable. There is still the possible issue of *sustainability*, however.

6.2.2.1.1 Planning and Implementation of Deployment

In the first study, rooms and scheduling were a big issue. The deployment was moved around between rooms, and had to be constructed and packed away every session. The initial agreement about the number of sessions changed due to other commitments within the school. These factors are the reality of school organisation. In the second study, there was a greater understanding of these practicalities. Redundancy was built into the schedule; such that school events made minimal impact and a single room could be used throughout the study, (sessions that were double booked were cancelled). This was achieved by spending more time in the planning stage with the teacher and school before the study began. Similar considerations would be required for longer-term deployments, where similar buy-in would be required at the school level.

6.2.2.1.2 Designing the Application for Everyone

This is one of the areas that Kharrufa et al. [58,59] suggested as an improvement to the first study – incorporating more orchestration tools and visibility into the application for the benefit of teachers. Teachers from the first study did not notice aspects of the design such as visibility of progress (showing current stage and cumulative progress in the writing task). For the second study, the teacher's *input into the design* was directly sought, allowing relatively minor changes to be implemented. In particular, this allowed the order of stages to be changed to suit her teaching agenda. Even these minor changes improved the teacher's

relationship with the technology, indicating that treating the teacher as a co-designer might be more important than any particular technology intervention.

Extending this concept to a school-wide, long-term deployment of the technology would necessitate a broadening of the term “everyone”. Beyond a single classroom / single teacher scenario obviously requires consideration of multiple teachers, each with differing agendas, but also input at the departmental and school level. The application would need the flexibility to cope with differing and sometimes conflicting demands from multiple potential co-designers.

This ties in with the concept of *integration* from Dillenbourg and Jermann’s orchestration model [27].

6.2.2.1.3 Teacher’s Need Experience in Using the Technology

The first study incorporated a “training day” for the teachers to visit the university and try out the software. This took the form of a standard presentation followed by an opportunity to “play” with the technology. At the time, all the teachers were happy with the technology and left the session “knowing” how to use it. When it came to the actual study, this proved to be insufficient, and teachers struggled with the technology. For the second study, the teacher went through two sessions in the role of a student, i.e. using the software from start to finish. In the study itself, the teacher showed greater familiarity with CCW during the sessions. For this teacher, two sessions seemed sufficient, but a larger study would be required to optimise the process. The train the teacher model (TTM) developed by Robertson et al. [106] addresses these “training” needs. However, training is a loaded word in this context, it implies that the researchers “know what’s best”, that CCW is already a proven solution, and the teachers are deficient in their knowledge. The reality is that the deployment is an experiment, and requires the expertise of all parties involved, researchers, teachers and students.

6.2.2.1.4 Understanding the Limitations of the Technology

The teachers in the first study attributed orchestration functionality to the digital tabletops that did not exist. The tables were at various times expected to monitor and regulate progress, regulate behaviour and differentiate at least at the group level. While all these factors would be desirable (and indeed form some of the recommendations from the work of Kharrufa et al [58,59]), they were not present

in the technology. The knowledge of these possible misconceptions however allowed the teacher in the second study to be adequately briefed on the limits of the technology.

6.2.2.1.5 Teachers Need to "Own" the Technology

Despite creating their own content for the collaborative writing application, the teachers in the first study saw the technology as a tool for the students only, rather than as a tool to help their teaching agendas. The teacher accomplished this by incorporating the technology directly in lesson plans and tying it to specific learning outcomes, the teacher in the second study began to see the potential of the technology as belonging to her and the students together as a medium for learning. The fact that she was involved with some of the design choices before the study also helped make the technology something she wanted to succeed. Ownership of the technology gives teachers the tools they need to express *leadership*, and allows for *flexibility* and *control* (Dillenbourg and Jermann [27]). It also allows for imbedding the technology in the teacher's agenda, i.e. *curriculum relevance* and *assessment relevance*.

For a longer-term school-wide deployment, a more involved design process may be required to make sure all stakeholders have an opportunity for design input.

6.2.2.1.6 Reliable Technology

The tables had several technical issues in the first study that were largely fixed by replacing the touch screen components for the second study. However, a significant factor in the opinion of how well the technology works is the engagement of the parties using it. In the first study, once the students had some problems with the technology, both the students and the teachers seemed to give up on the task. When similar glitches happened in the second study (albeit less frequently), the attitude was that the work was experimental, and that the students and teacher were partners in the experiment and were motivated to make it work. Creating this relationship between the parties involved and the research goals makes the study more robust to these kinds of technical hitches. This is something that would also be required with a larger school-wide take up of

the technology, and ties in with the concept of *physicality* [27] as the technology (i.e. digital tabletops) become actors in the classroom (and school).

6.2.2.1.7 Give Students' Work Purpose

In the first study, it was made clear that the work was not going to be formally assessed, which led to a less committed cohort. For the second study, the teacher (and the school) agreed to give appropriate feedback (i.e. marking of work but also in-class discussion, model answers, and peer review etc.). Combined with the teacher's plans for each lesson that integrated the technology attainment targets, the students were more engaged, and generally seemed to enjoy the process far more.

Purposeful work is one way a teacher can exert *control* [27] over the classroom, and provide *Curriculum Relevance* and *Assessment Relevance*.

6.2.2.2 The Classroom as an "In the Wild" Context

The label "in the wild" is often applied to any deployment or study that takes place outside the lab [23], but of course, every "wild" is different. A classroom is fundamentally different from a care home, which is fundamentally different from an oilrig. Therefore, what are the characteristics of the classroom as an "in the wild" setting? The first thing to consider is the stakeholders, which are the learners, teachers and the school itself. Unlike a lot of "in the wild" deployments, where willing volunteers are recruited to test a new intervention, and are usually involved from a very early stage, perhaps contributing significantly to the design, in a school it is difficult to get all stakeholders on board at an early stage. This is particularly the case at the classroom level, where there are tens of simultaneous users during a single session. In both the studies conducted, there was an effort to recruit teachers enthusiastic about the deployment, or at least the potential. In both cases, at the early meeting stage, this process *seemed* successful, and it was only after the start of the first study that difficulties arose. Learning from and understanding why those difficulties took place led to a more successful second study. One of the key factors being that in the first study the learners felt that the study was not *for* them and as it was not being assessed in any way, that it was a waste of time. In short, the study was *imposed* on them without any visible benefit. For the second study, a more concerted effort was made to engage the learners, by

giving meaning to their work through feedback, and establishing the learners as research partners.

Another thing to consider is that "the classroom" is not a singular phenomenon. Various parameters fluctuate between "classrooms" that can cause differences in a particular study or even session. The biggest factor between the studies is that they were conducted in different schools. The two schools had differing cultures, the former focusing on attainment and imparting knowledge (i.e. acquisition rather than participation [118]) while the second had a skills development focus. This already predisposes the second school to embrace the kind of group based, transferable skills focused learning task for which the technology is designed. The teacher's attitude towards the technology is also a large factor – a teacher that feels like the technology is *for* them as well as the students will work towards making it succeed. Other factors, including seemingly mundane things such as which lesson the students had before a session, the weather outside, or the time of day can have an effect. Perhaps the studies should have been characterised as a deployment across a series of *similar wilds.*

6.2.3 Evaluating the Collaborative Writing Application in the Classroom

This design was then taken into an "in the wild" classroom environment for two studies, with the intention of evaluating CCW in order to address the second research question. The second of these studies provided useful evaluation of CCW, both for the learners and as a tool for the teacher.

6.2.3.1 For Learners

Due to the practical considerations of the deployment and availability of resources within the school, the study was not lengthy enough to show any significant improvement in persuasive writing among the learners. (Although the teacher did feedback that she saw improvement in writing structure related to the table). This was understood from the outset, so instead the analysis focus was on collaborative behaviour within a group across the study, and linking this to elements of the design that were intended to afford these behaviours, in particular discussion and use of the visuospatial interface to communicate ideas. These design elements

included **Decision Points, Paragraph Creation, Paragraph Connection** and **Use of Evidence.**

In the early stages of the study, student discussion was focused on the technology, requiring facilitator intervention to get "on topic" i.e. how to go about completing the task well or the themes of the content of the task. During the study however, CCW became more prominent in instigating "on topic" discussion through **Decision Points**. By the final session, learners discussed relevant topics on their own initiative, with the table being relegated to an implementer of ideas rather than a prompt.

Paragraph Creation was also an area where discussion occurred. The group began with generic paragraphs, but in later sessions the paragraph naming became more content focused, and the students began to see common themes across the sessions, showing a deeper understanding of the underlying topic and of their own writing skills, a pattern that also became evident while **Connecting Paragraphs**.

The group began the study by using the supplied evidence minimally, instead writing their own evidence into the plans on a largely individual basis. After a classroom teacher intervention, the groups **Use of Evidence** became more about selecting the "correct" evidence – a process that led to behaviour that is more discursive. By the end of the study, the group were engaging in discussion before successfully mixing their own evidence with the supplied evidence slips to make specific persuasive points. The data suggests that the design decisions made in the development of CCW were broadly able to support collaborative behaviours, as well as help students learn how to write collaboratively.

6.2.3.2 For Teachers

The teacher in the second study had early input in the use of the technology, by tweaking the design (by re-ordering the stages) to fit her teaching agenda. She also created all the content for the study.

By integrating the technology into her lesson plans, and providing reflections after each session, the relationship the teacher had with the technology can be observed. While incorporating the technology into her classroom may have begun as a challenge, over the sessions the writing application became more integrated into her teaching. Initially, like the students, her focus was on the

technology, and how (or if) it would work for her. As the study progressed, her focus became more on the *task* (i.e. planning for persuasive writing). She began to see the technology as a useful tool for *her agenda*. By the end of the study, she had suggestions about improving the task to fit better with the requirements of persuasive writing (alternative visualisations, themes for paragraph outline points etc.).

6.3 Limitations

One significant limitation of the work presented is the timescales involved. Although the work presented in this thesis covers a learner based design process, which took place over several weeks, and two large-scale studies in classrooms, each taking eight weeks, this was not enough to provide enough evidence for a definitive longitudinal effect on learning for the learners involved. Instead, the work gave insight into design requirements for applications of this nature, as well as how to deploy this kind of technological intervention into the classroom environment.

The Extended Writing task itself could also be improved. It concentrated on only one genre of writing, Persuasive documents, and while this was sufficient for the studies, for longer-term use-cases, the software should support several genres to allow for lessons not focused on a single genre. Even within the persuasive document genre, there are several areas of improvement suggested by the teacher involved in the final study. Some way of labelling parts of the document (either at paragraph level or lower) with specific persuasive argument types, such as anecdotes; facts; opinions; statistics; expert evidence; emotive language; rhetorical questions etc. In addition, supplementary supporting graphical tools to weigh up evidence, such as literal “scales” or a Venn diagram.

The technology itself also limited the scope of the research. Although initially designed on pen-based tables, where users can be readily identified, due to practical concerns (such as available space and tables) the two studies were conducted on multi-touch tables. While there are advantages for using such tables, such as familiar gestural interactions, the disadvantage of not being able to identify users made analysis of table usage difficult.

6.4 Future Work

6.4.1 Longitudinal Study

To establish a learning outcome such as improved Persuasive Writing composition would require a longer-term deployment with appropriate pre and post-tests. However, the lessons learned from the two studies, in particular with regard to differing expectations, could be used to model larger scale, school wide deployments. Some of the solutions for the problems encountered would have to be re-worked in order to scale up, but the concept of establishing a platform that implements teaching agendas as well as supporting learning is a crucial one.

An example study might have the following properties:

- Conducted over a longer time period, e.g. 1 year.
- Conducted across multiple classes or schools.
- Curriculum and materials designed by participating teachers to fulfil their teaching goals across the length of the study.
- Utilising a control class to measure against (using same curriculum / material)
- Pre-tests and post-tests designed to specifically measure writing ability or attainment.

6.4.2 Application Design

The collaborative writing application was designed to facilitate the learning of Extended Writing, in particular in the persuasive writing genre. That is, it was designed for one type of audience, in one particular genre of Extended Writing. This suggests several possible areas for improvement.

6.4.2.1 Improve Parallel and Collaborative Working Mechanism

As outlined in Section 6.2.1.4, the mechanism for switching between parallel and collaborative working has potential problems. It is forced, binary, immediate and unilateral. A better design might allow for a gradation between two working modes – users would be able to "escalate" the need for collaboration, with suspension of the interface being a last resort. It could also be possible to indicate a user's intention to suspend the interface rather than it just happening, and that

would give other users a warning, and an opportunity to decline (via some kind of voting mechanism). In any case, a method for users to decide together to concentrate on a particular decision and suspend the interface could prevent loss of concentration on individual tasks.

There may also be other mechanisms to increase group collaboration through discussion, such as presenting work done in parallel to the larger group through an explicit stage in the process, or the application presenting discussion questions about particular decisions (why do you think x and y belong together?).

6.4.2.2 Support More Aspects of Writing

CCW currently focuses on the planning stage of an Extended Writing task. Indeed, final text entry was removed from CCW in the final study to allow for individual assessment, and because the text entry method (i.e. a single keyboard) was inadequate for collaborative work. Adding text entry functionality would broaden the scope of CCW, allowing for the option of text generation if appropriate for the lesson objectives. To this end, technology such as handwriting recognition [99] might make a better interface than the keyboard approach.

6.4.2.3 Better Persuasive Writing

The first area that could be considered for improvement is making the Collaborative Writing Application better suited for persuasive writing. During the second study (Chapter 5), the Teacher suggested some areas in which CCW could be improved to make it a better tool for representing a persuasive argument. These include categorising specific paragraphs or arguments in the plans using common types of persuasion, such as anecdotes; facts; opinions; statistics; expert evidence; emotive language; rhetorical questions etc. Another suggestion was extra graphical tools allowing comparison of pieces of evidence, such as a Venn diagram tool, or "weighing scales". These would need to be carefully designed so as not to break the "visuospatial elements" ethos of the overall design.

6.4.2.4 Support More Extended Writing Genres

Currently, the Collaborative Writing Application only allows for one type of Extended Writing document – persuasive writing. CCW could be extended to support other genres, such as Discussion, Procedural, Explanation, Report or

Recount [76]. As with the design for the current application, visuospatial elements should be chosen to reflect the direct aims of each genre. For example, Discussion, which is similar to Persuasive, may also use Evidence as a key element, but this would not be the case for a Recount genre, where a series of time-stamped activities may be more appropriate.

6.4.2.5 Collaborative Writing as a Tool for Experts

Several times during this work, adult observers have seen the potential benefit for such a tool in their own collaborative writing. That is, instead of a tool for learning how to write, CCW could be adapted as a tool for producing document plans among expert users. This would require CCW to allow a "free" mode without interference from the table, and possibly a redesigned interface to allow for longer, more complicated documents. There could also be a method to assign pieces of writing to individual authors within the plan. One scenario could be collaborators co-authoring a research paper, where reference papers, experimental results etc. could form the evidence elements.

6.4.3 Other Learning Tasks

The Collaborative Writing Application design centred on converting a non-collaborative learning task, the composition of Extended Writing in the persuasive writing genre, into a collaborative one by utilising visuospatial elements to represent key processes in the task. A similar procedure could be applied to other learning tasks also considered as being focused on individual learning. In many cases, these tasks are composition tasks – other tasks such as reviewing or debating can more naturally be adapted to group work.

Computer Programming as a field has several visuospatial learning applications, such as Scratch [102], and Visual Programming in general has long been a field of interest in computer science [85]. However, these applications tend to be aimed at individuals, at least in the sense of the manipulation of the programming elements. In order to benefit from the advantages of collaborative learning, applications would need to be designed to regulate collaboration. That is, to have a mechanism similar to decision points that brings learners together to discuss problems and achieve consensus.

The composition of music could be a task that could be made collaborative by using a visuospatial shared collaborative space. There are examples of music composition applications that build on visuospatial elements already (for example [17]), though they are still geared towards the individual. Again, a mechanism for regulating collaboration would be required.

6.4.4 Orchestration

The focus of this work has been on the design and classroom integration of the Collaborative Writing Application. Part of the activity in any classroom is the orchestration conducted by the teacher [14], that is the real-time management of activities in the classroom, including learning processes and other teaching actions [27]. During the studies, the responsibility for this was largely left to the teacher, with little support from the technology other than an attempt to make progress of the task visible to teachers (with varying success, as the teachers in the first study noted). In fact, in both studies the teachers displayed their expertise by utilising 'traditional' orchestration methods, such as bringing the class together to highlight an interesting event, or using the whiteboard to provide an introduction and prompts to students in a public, visible way.

Section 2.7.1 goes into more detail about the concepts of orchestration and some of the technologies that have been implemented to assist with the activity in the classroom, such as TinkerLamp [34] and SynergyNet [1] . These technologies tend to focus on giving the teacher, or the class as a whole, a centralised system for monitoring progress (allowing for regulation in the classroom). In some cases, the teacher is given further control, to stop interaction (to gain the classes attention), or intervene in groups' activities [44,83]. Kharrufa et al. [59] provide an analysis of the current work on integrating digital tabletop systems and technology supported orchestration.

So how could the Collaborative Writing Application benefit from technology-enhanced orchestration? The first thing to consider is if it is required at all – various teachers in the studies had different orchestration strategies, and while some could benefit from a system, some could find it obtrusive. In a sense, this is a similar problem to the one faced by CCW itself, and one that is faced by any technology intervention in the classroom. In order for the parties involved to adopt

the technology, they must see a benefit for themselves. The technology must allow them to execute their own agenda, but it can also be used to change the construction of their role. In this way, a similar exercise to the first study, concerned with obtaining expectations from all parties about how a system would function, and understanding the limitations, would be necessary as part of the design process.

The second factor to consider is the design of the system itself. There may be some basic operations that are ubiquitous across all orchestration systems, such as monitoring progress or freezing the students' technology in order to gain attention. However even this basic freezing action does not replicate an orchestration activity in a non-technical classroom directly, and teachers often have to use other techniques to gain attention, which may well need to be used in conjunction with the technological solution. Going further than these basic requirements requires close integration with the task. Different tasks will have different requirements. It may be the case that there is no "generic" orchestration technology that can be applied across multiple tasks, and it might be more sensible to think of orchestration as an extension of a specific task rather than as a separate activity.

There is scope, however, for technology to provide key orchestration actions that can enhance a learning activity. Providing real-time monitoring, other than full screen renderings of each group requires some visualisation design. In the case of the collaborative writing application, this could be similar to the interaction log visualisations presented in Chapter 4 and Chapter 5. This is similar to how Digital Mysteries presents playbacks for reflection sessions. CCW itself could provide onscreen feedback for progress; comparable to how Digital Mysteries displays time spent on stages and user interactions (when users can be identified). Real time differentiation is also a key aspect of orchestration, helping struggling students and giving high achievers activities that are more challenging. This can be done through teacher interventions either directly on the Digital Table, or from a central control system (e.g. for whole class interventions). For the Collaborative Writing Application, this could take several forms. The simplest is the advancing of struggling students through stages artificially, lowering requirements or omitting stages altogether – a more advanced form of this would be providing partial

answers that allow the students to progress more quickly having seen exemplar material. Teachers could also highlight key evidence data items (or groups of data items) that students should focus on as being a cornerstone of their argument. For higher achieving students, extra evidence data items could be added to make the argument more difficult, or increasing the requirements for completing a certain stage.

The overriding theme emerging is that technology enhanced orchestration is a tool for the teacher to implement their desired interventions, not a replacement for traditional methods, but an extra facility.

6.4.5 Technology

The technology used in the studies had issues with responsiveness and reliability (as well as portability and comfort of the users). Improvements in the underlying technology, such as larger LCD based tables rather than the projection-based tables used would solve many of these problems. The higher resolution of modern tables would also allow clearer representations and more detailed evidence data items to be supported. Currently, there is no easy way to identify users on the Multi-Touch Digital Tables used for the studies, a disadvantage compared with the pen tables for which the collaborative writing application was originally designed (especially for monitoring individuals in the interaction logs). Promising technology is being developed, however that utilises accelerometer watches to match touch patterns with an individual – so a best of both worlds scenario may soon be possible, incorporating identifiable users and gestural interaction.

Aside from improving the digital tables, an interesting area of exploration would be to adapt the collaborative writing application for other technologies. Digital Mysteries has been developed commercially [62], and has been adapted for multiple-mouse interaction on an "ordinary" desktop computer, as well as tablets. Using ordinary computer systems have the advantage of their ubiquity and cheapness. Obviously some of the collaborative affordances of the table are lost, such as the horizontal shared space, face-to-face collaboration and the fact that a vertical screen is no longer simply collaborative but also public [26]. Tablets can be used in a similar way to Digital Tables, provided they are placed in a horizontal

orientation. Their size limits the number of users; however, large-scale tablets are in development by several companies.

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Appendices

Appendix A: Digital Mysteries

Learner Centred Design

Will Kyle Go To School?

On Tuesday 9th October, Kyle was late for a lesson for the twelfth time since starting Year 7.

Kyle's Mum works from home.
She is quite strict.

On Thursday 11th, the caretaker told Mr. Smith that he'd seen Kyle and James in the staff car park on Wednesday afternoon.

On Wednesday 10th October, the Head of Year 7 had to go home in a taxi.

On Wednesday evening, Kyle's Mum confiscated his mobile phone during the 10 o'clock news.

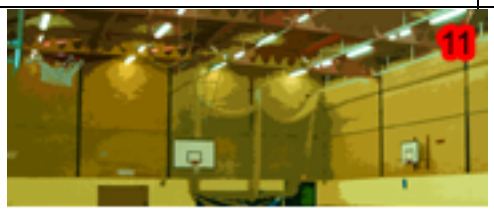
Three students from Form 10A have been permanently excluded since September.

Kyle likes his Head of Year, Mr. Smith, because he is very friendly and easy to talk to.

Kyle's form room is at the far end of F corridor. You have to go past 10A's form room to get there.

At Valley High School, girls are allowed to wear make up.

Four people in Kyle's tutor group are very badly behaved in lessons.



The sports facilities at Valley High School are much better than at Kyle's previous school.

At Valley High School pupils from all year groups can mix together at lunchtimes.

At lunchtimes, Kyle has started to hang out with much older pupils.

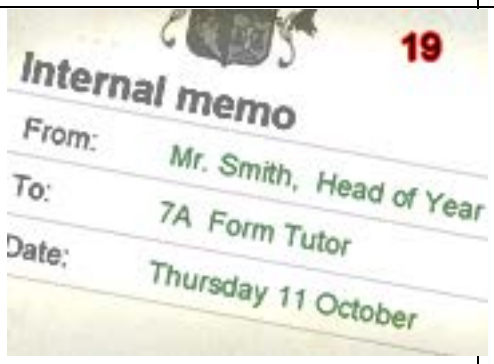
Kyle's ICT teacher has been off sick since the beginning of the term.

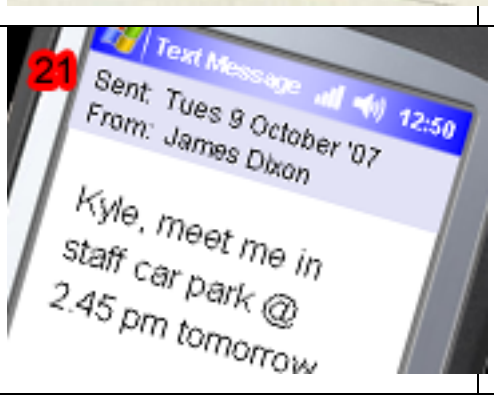
Davie Dixon from form 10A, was Kyle's 'buddy' for the first two weeks of term. They had got on really well.

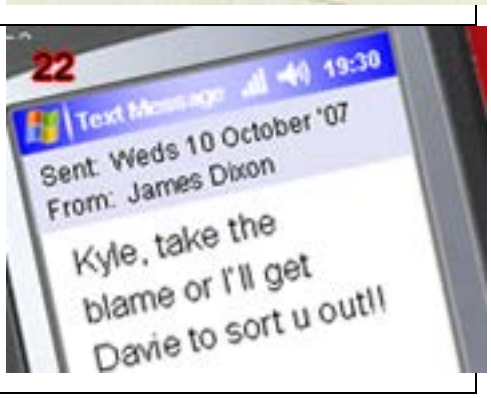
For the first two weeks of term, Yr 7 students were matched with a 'buddy' from Yr 10 to help them settle in and find their way around.

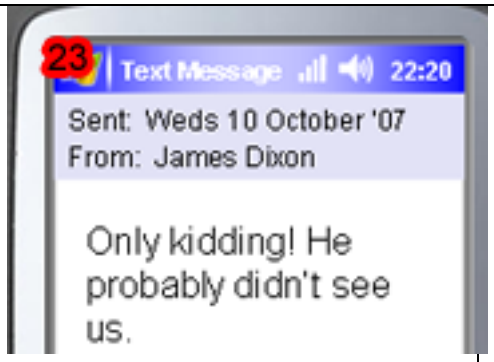
By October, Kyle had made just one good friend – a year 9 student called James Dixon.

Year 7 tutor groups stay together for all their lessons except English, Maths and Science.





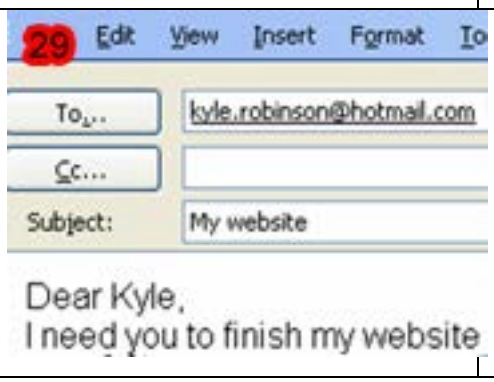


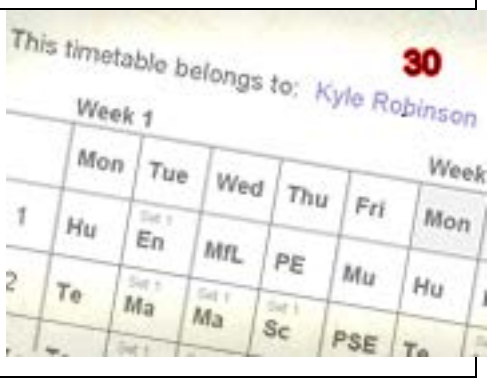


Incident no. 87:
10 October 2007 Valley High School

F corridor - Agenda item no. 1 The most dangerous corridor in the school!

At Valley High School, Year 7 students like to express themselves.





Should Annie Leave Windy Creek?

There are only 4 stores in Windy Creek - foodstore, hardware, clothes and hairdresser/drugstore. There is also a filling station with a diner/bar.

The summers are hot and sunny. The winters are cold with plenty of snow.

Her boyfriend, who she met at college, lives in Arizona.

Annie's best friend Beth is married and lives on a ranch 15 miles away.

Half the people in Windy Creek are over 50.

Annie has 3 uncles, 4 aunts, 3 grandparents and 7 cousins in Windy Creek. She loves the family get-togethers.

In 1939 the population was 1370 - there were more shop and a cinema.

She cannot afford a car on what she earns.

9

She has been offered a job as a trainee manager for a car leasing firm in Tucson, Arizona.

10

Annie suffers from allergies especially in summer.

11

The Windy Creek is a beautiful river. Its water in summer comes from melted snowin the mountains. It is clean and clear and great for swimming.

Annie has been to college and is qualified as a business manager.

12

13

There is an elementary school in Windy Creek

14

Annie loves skiing, canoeing and backpacking.

15

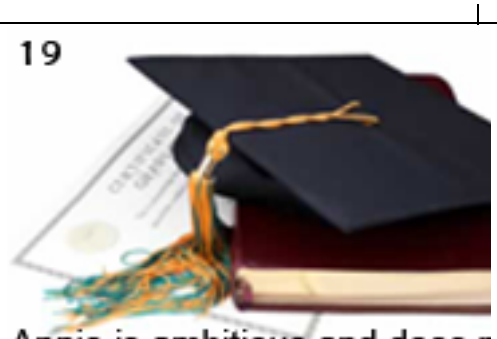
The nearest cinema and fashi shops are in Laramie, 80 miles away

16

Annie Schmidt lives in Windy Creek, Colorado. 620 people live in the town.

The only job that she can get
serving at the diner and as a
part time ski instructor in winte

She lives with her mother
who is divorced.



Annie is ambitious and does n
want to waste her education.
But she does love Windy Cre

There are plans for a 'dude' ranch
6 miles outside Windy Creek.

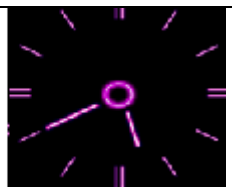
Who died in the Kobe earthquake? And why?

Many survivors were taken
immediately to a central building with
stockpiles of food, water and blankets.

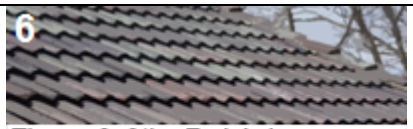
5000 people died in the earthquake
and 350,000 were made homeless.

Gas pipes exploded and fires burnt
all over the city.

4
The earthquake
struck at
5.40. a.m. on
Tuesday 17th
January 1995.



Some buildings in central Kobe
have structures which are
computer controlled and adjust to
earth movements.



The roof of the Endo's house was
made of heavy concrete tiles.

7

Southern Japan, where Kobe is located, has not had a major earthquake since 1596.

8

Japan is a rich country. It is one of the most technologically advanced countries in the world.

9

Kobe was very close to the epicentre of the earthquake.

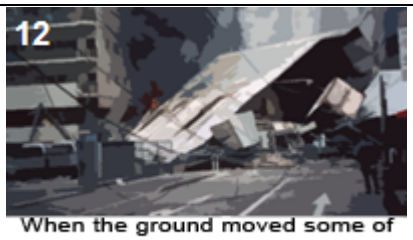
10

Many fire engines ran out of water before the fires were put out.

11

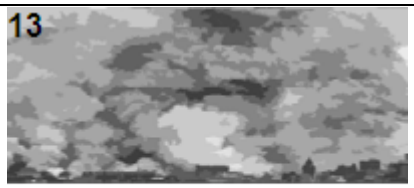
Several hospitals in the old part of Kobe were destroyed in the earthquake.

12



When the ground moved some of the buildings did not follow and collapsed.

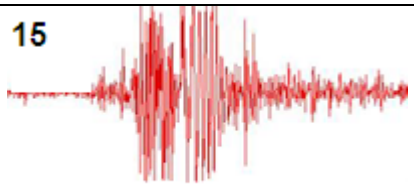
13



Large areas of Kobe were blacked out because electricity lines were cut. With the smoke from the fires the search for survivors was difficult.

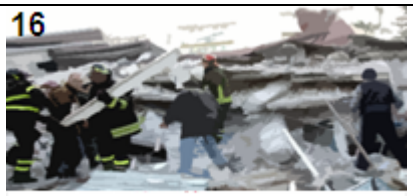
14 There is a Japanese saying - "The devil will pass over a house with a good roof and move on to the next one."

15



More than 600 aftershocks followed the earthquake.

16



Volunteers dug through the rubble with their bare hands to search for victims.

17

Mrs Endo was trapped under the rubble of her home and died of suffocation after 36 hours.

18

The port of Kobe, the world's largest container port, was destroyed.

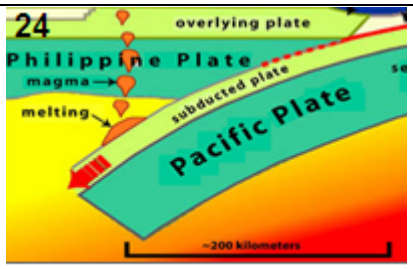
Mr & Mrs Endo lived in the older residential part of Kobe called Nishinomiya. Most of the people who lived here were old.

The Endo's son, Kazuo, lives in a new apartment block in central Kobe.

Underground water pipes were broken by the tremors.

The Endo's house was built before 1960.

Mr Endo visited his son on the evening of 16th January and spent the night there.



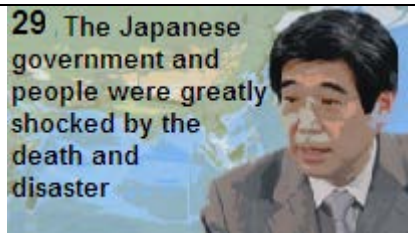
Stress builds up in the rocks of the Pacific and Philippines plates.

Since 1981 Japanese houses have been built to be earthquake proof.

Kazuo, helped by friends, found his mother's body at 1.20. pm. on 19th January.

Ambulances and fire engines were unable to reach damaged areas because the roads were blocked by collapsed buildings.

When stress is released from rocks at plates boundaries by moving, waves travel through the earth's crust.



Japan has a population of 124 million and a population density of about 310 per sq. kilometre.

Study One

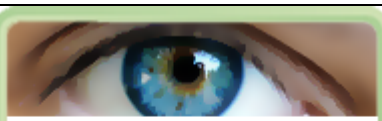
English

Jenny and Amina are writers for their college newspaper 1

Three brothers, Damien (32), Jason (28) and Richard (25) Henderson own High Falls Farm 2

There is a camping barn at High Falls Farm 3

The nearest pub does good bar meals 4



When the girls arrive at the farm Jason opens the door. He has shoulder length brown hair and piercing pale blue eyes 5

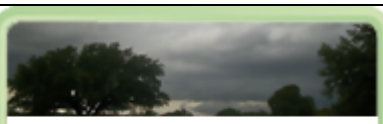
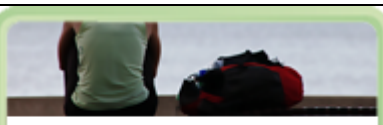
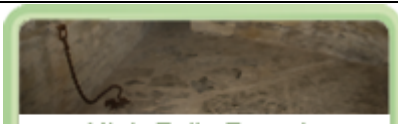
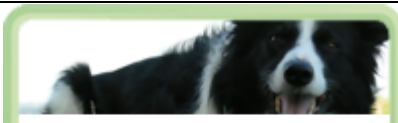
Jenny and Amina decide to visit High Falls in October, as background to a story about an unexplained death of a girl they knew 6

Harry Henderson, the boys' father, committed suicide soon after Damien left for university 7

Amina is very excitable and ambitious to be a journalist with a national newspaper. Jenny is very clever but a bit shy. 8

Richard Henderson is quiet. He has had a short spell in hospital with depression. 9

High Falls is a sheep farm in the Pennines. The nearest house is 1.6 miles away 10

 Amina and Jenny walked 6 miles to get to the farm. It was gloomy with steel grey skies seeming to pressing down on them. 11	 Jenny says 'We were just going to cook supper'. 12
 Sadie Devreaux, a Canadian backpacker was found dead in the water at the falls in September the previous year. 13	 At 6 p.m. Jason knocks at the 'barn' door and says would the girls like to see the falls, before dark, and then go to the pub? 14
 Josie Henderson, the boys' mother 'left' when Damien was 12. 15	 High Falls Farm is attached to remains of a castle tower. There is said to be dungeon underneath it. 16
 Richard looks after the sheep. His collie dog Jordan is devoted to Richard and she will attack anyone who seems to threatens him 17	 Amina is fascinated by Jason – she tells Jenny that his blue eyes send shivers down her spine 18
 Sadie and Becky were the only guests in the barn at the time of their deaths 19	 High Falls is the third highest waterfall in England. The best view is obtained from the rocks at the top 20

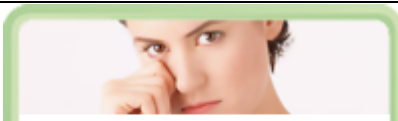
Jason tells the girls that he would rather take them as the rocks are slippery and there have been two terrible accidents. 21

Becky Dunn, a college student was found dead below the falls in May. 22

As the girls get in the Land Rover in the rain, Richard comes running, wild-eyed, from the house shouting 'Wait, WAIT, don't …' 23

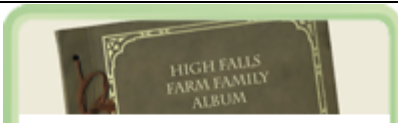
According to his brothers, Damien lives and works in London as an architect. He never comes home. 24

Jason looks after the camping barn and the holiday cottage. He also does web design. 25



Josie was considered a great beauty with pale blue eyes and brown hair. She was always unhappy at High Falls. 26

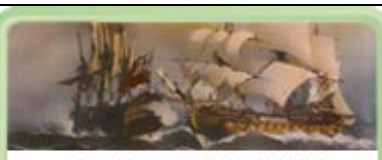
Richard uses an internet dating agency. Sadie had a picture of him in her luggage 27



Jason has told Richard that they must stick together – they are family. 28

History

She ruled England for 45 years. The fifth longest reign of any English monarch. 1



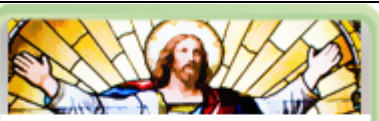
Her navy defeated the Spanish Armada. One of England's greatest ever victories. 2

During her reign England became a much safer place to live for most people. 3

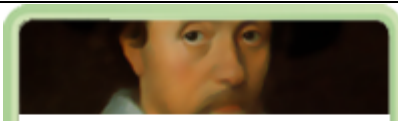
The gap between the earnings of the rich and poor increased over her reign. The rich lived in luxury, the poor had very little. 4

The famines of 1590 caused many of the poorest people in Elizabethan England to die of starvation. 5

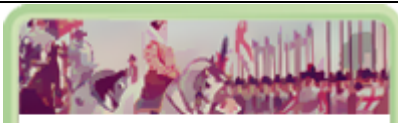
Elizabeth never married and had a son. This meant that the Tudor name did not carry on. 6



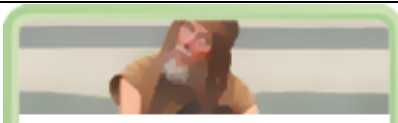
Elizabeth made sure that England was a Protestant country by the time that she died. This did not please everyone, especially Catholics. 7



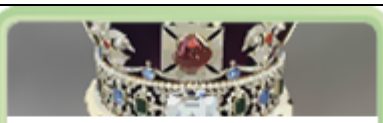
Elizabeth was succeeded by her cousin James I of Scotland. He was not always very popular. Some men even tried to blow him up after he became king because he didn't like Catholics. 8



Elizabeth did not involve England in many wars in Europe. This meant that England was sometimes seen as weak by other nations. 9

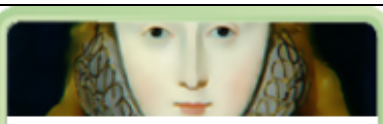


There was no money given by the Queen to help the poor and unemployed. This meant that some of the poor and needy went round the country begging. 10



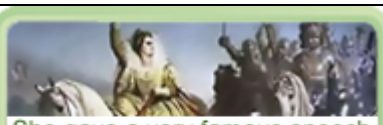
Elizabeth was an incredibly vain person. She spent a huge amount of money on make up and jewellery. 11

When she was crowned as queen the celebration banquet cost £16750 (about £3.5 million in today's money) 12



There were many plots to try and remove Elizabeth from the throne. One of them even involved Elizabeth's cousin, Mary Queen of Scots. 13

Elizabeth could speak a number of languages and was seen as very intelligent. This was at a time when very few women were educated at all. 14



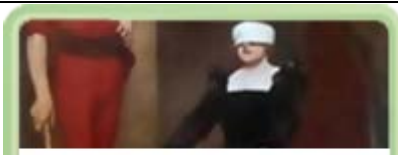
She gave a very famous speech to her soldiers in 1588 as the Spanish Armada was getting closer to England. This is seen by some as an inspiration for the soldiers and sailors. 15

16

Elizabeth used make up which contained lead and other poisonous chemicals. It made her face very light (which was the fashion of the time) but it eventually caused terrible damage to her skin.

17

England didn't have an empire like Spain or Portugal to bring home lots of gold. Instead, Elizabeth paid 'privateers' to go and steal the gold that was being sailed back to Spain and Portugal.



Elizabeth ordered the execution of her own cousin Mary Queen of Scots. 18

19

20

Geography

I was starving and I found some old fruit from a market stall. I ate it and fell asleep 1

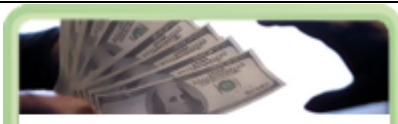
My baby brother died a week ago and my sisters are not well. 2

The soil around our shamba is getting poorer each year. 3

A man from our village joined the army. He told us stories about all of the food and drink they had when they went to Nairobi. 4

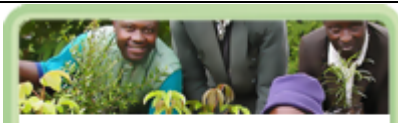
I got a job picking coffee on the plantation. The manager said that I worked well for a skinny little boy, so I thought that I could easily find work in the city. 5

My mother gave me some money because she thought it would help me find my feet in the city. 6



I gave a man my money and he promised that he would find me a job. He said he would be back in an hour, but he must have been delayed. 7

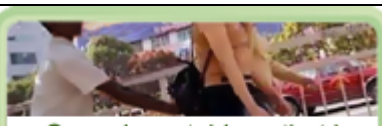
My father used to bring his toy animals to the city to sell them to the tourists. 8



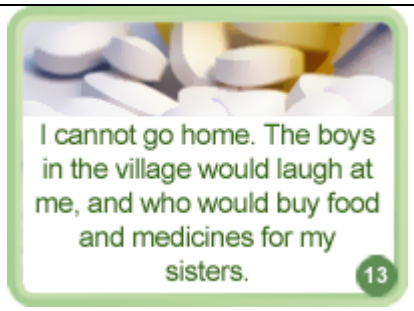
Another of our neighbours went to the city. He sent back enough money so that his parents could buy some extra land. They are rich now. 9

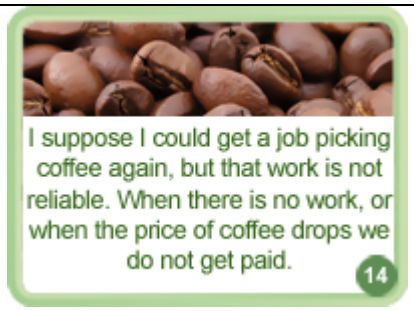
The man who drives the truck to take the coffee to the packers gave me a lift to the edge of Nairobi. 10

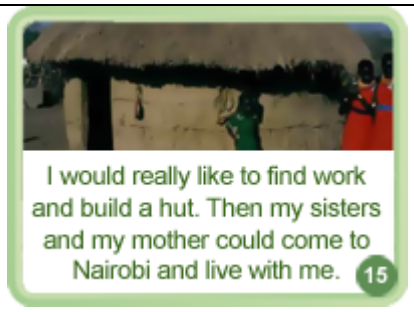
My cousin lives in a hut on the edge of the city, but I could not find it. 11

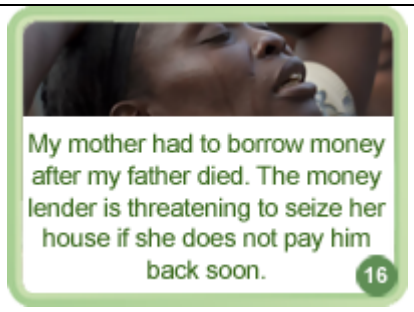


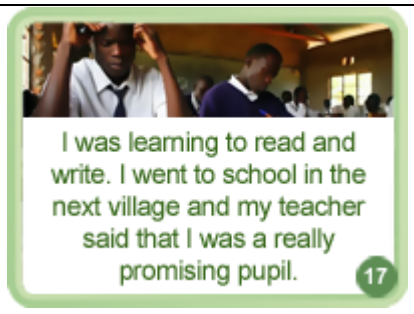
Some boys told me that I could beg or steal if I got into the city centre, but when I got there I was too frightened to try. 12

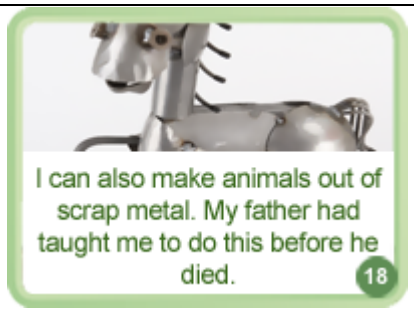


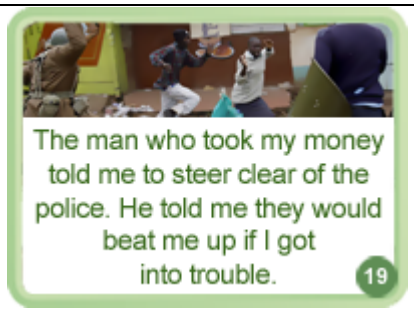


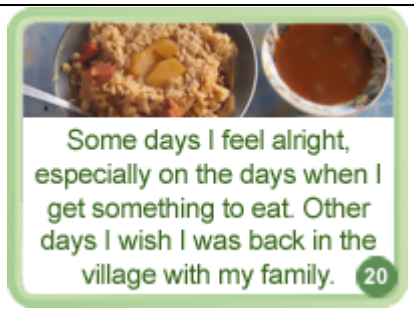






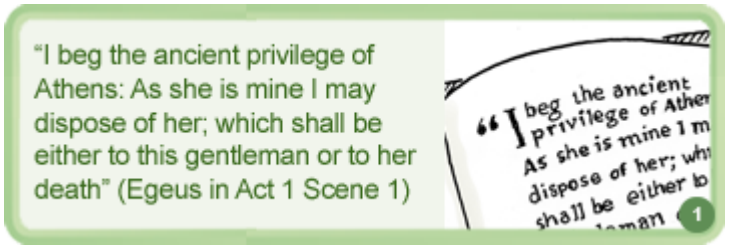




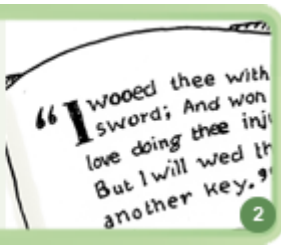


Study Two

A Midsummer Night's Dream

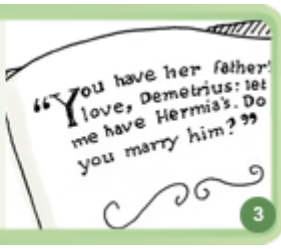


Theseus is to marry Hippolyta, having already defeated her in battle. "I wooed thee with my sword, And won thy love doing thee injuries. But I will wed thee in another key." (Act 1 Scene 1)



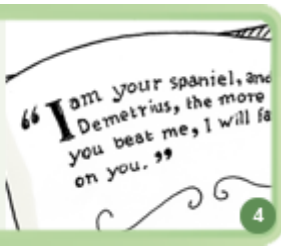
2

"You have her father's love, Demetrius: let me have Hermia's. Do you marry him?" (Lysander teases Demetrius in Act 1 Scene 1).



3

"I am your spaniel, and, Demetrius, the more you beat me, I will fawn on you" (Helena chases Demetrius in Act 2 Scene 1).



4

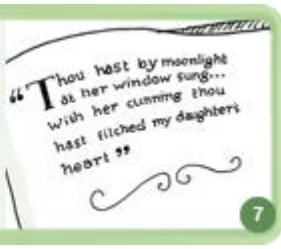
'A Midsummer Night's Dream' was probably written around 1595-1596.

5

Oberon scolds Puck for either his error or his mischief when enchanting Lysander by mistake in Act 3 Scene 2.

6

"Thou hast by moonlight at her window sung…With cunning thou hast filched my daughter's heart" (Egeus complains about Lysander's courtship of Hermia in Act 1 Scene 1)



7

Titania points out in Act 2 Scene 1 that her fight with Oberon has caused terrible turmoil in the natural world; floods, storms etc.

8

Midsummer Night was often marked by Elizabethans with parties that celebrated enchantment, witchcraft and sometimes even madness.

9

"I jest to Oberon and make him smile" (A jester was allowed to befriend and entertain the king; this is Puck's job.)

10

"I know not by what power I am made bold… My soul consents not to give sovereignty [to Demetrius]" (Hermia stands up for herself in Act 1 Scene 1).

11

It is thought this play was written as part of an important marriage celebration. It explores and celebrates love.

12

In Act 1 Scene 1, Lysander persuades Hermia to run far away with him, so they can be married away from Athenian Law.

13

"Fetch me that flower…" (Oberon asks for a magic flower that will make someone fall in love with the first thing they see in Act 2 Scene 1).

14

"I am that merry wanderer of the night" Puck introduces himself in Act 2 Scene 1 as a maker of mischief and trickster).

15

This play has influenced many throughout the centuries; there is a famous ballet based on this story, as well as many works of art.

16

Hermia is short and dark, while Helena is tall and blonde

17

'Lunar' means 'moon', and from this word we take the word 'lunatic', meaning someone who is mad. There are a number of mentions of the moon throughout the play.

18

"Shall we their fond pageant see? Lord what fools these mortals be!" (In Act 3 Scene 2, Puck is amused by the effects of love on ordinary humans, and the results of the enchantment.)

19

Hermia is warned in Act 1 Scene 1 that she must either choose to obey her father in his choice of husband, or else become a nun or face execution.

20

In Shakespeare's time marriage among the wealthy was not for love – it was, in effect, a business contract between wealthy families.

21

The play ends – like many of Shakespeare's comedies, with a marriage and celebration or feast. The three newly married couples have their unions 'blessed' by the fairies.

22

It was the job of a 'fool' or 'jester' to entertain the king with jokes and comic relief, but they also had an important function. They were allowed to be cheeky and sometimes rude to those in authority to 'keep them on their toes'; the Fool in 'King Lear' is a special character who is allowed to challenge the King in ways that no one else would dare.

23

"Ill met by moonlight, proud Titania!" (In Act 2 Scene 1, Oberon accidently meets his queen at the height of their row over the changeling boy. The night is raging with storms and turmoil as a result of their quarrel)

24

The rude mechanicals hide in the forest to rehearse so that other people don't see them, although the magical creatures can observe them.

25

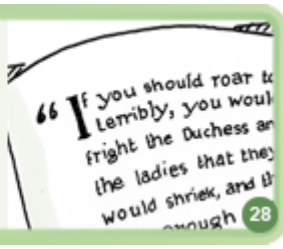
"I had a dream, past the wit of man to say what dream it was. Man is but an ass, if he go about to expound this dream" (In Act 4 Scene 1, Bottom wakes up, groggy and confused, but without the Donkey's head Oberon had given him earlier).

26

At the end of the play, Puck addresses the audience directly – he 'steps out of the performance' to ask forgiveness for any offence caused; "think but this, and all is mended, That you have but slumbered here" (Act 5 Scene 1)

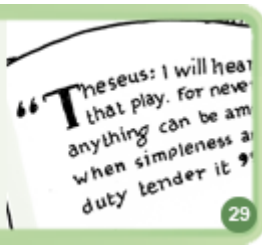
27

"If you should [roar] too terribly, you would fright the Duchess and the ladies that they would shriek, and that were enough to hang us all" (Peter Quince shows that he is worried that their play could be too realistic for the audience in Act 1 Scene 2).



28

"Theseus: I will hear that play. For never anything can be amiss, When simpleness and duty tender it" (In Act 5 Scene 1, Theseus chooses to have the workers' play performed, and shows sympathy to actors who desire to give pleasure and entertainment to their audience.)

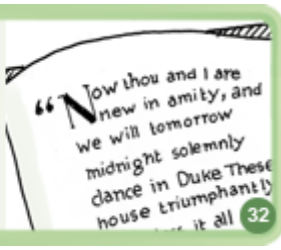


29

There is a resonance for the lovers who are watching the tragic story of Pyramus and Thisbe at their wedding feast; days earlier Hermia herself faced death for the sake of love.

"My mistress with a monster is in love" (In Act 3 Scene 2 Puck notices that Oberon's plan to bewitch and control Titania by means of the enchanted flower has worked.)

"Now thou and I are new in amity, and we will tomorrow midnight solemnly Dance in Duke Theseus' house triumphantly, and bless it all to fair prosperity" (Oberon and Titania are reconciled in Act 4 Scene 1, and restore peace to all around them.)



The play ends with a common Shakespearian device; the characters are watching other characters performing a play. This 'play within a play' scenario also occurs, for example, in 'Hamlet' and 'Loves Labours Lost'.

Greek Mythology

1. Fitness and athletic skill were greatly prized by the Greeks; heroes such as Perseus and Odysseus were strong and skilled in skill such as archery, running and field sports.	2. 'Xenia' is a Greek word for 'hospitality'. It was important for Greeks to help and support travellers.
3. Often people and gods change their form in Greek tales. E.g. Circe changes Odysseus' men into pigs, Artemis becomes an owl, Zeus takes animal forms to access human women etc.	4. As well as physical strength, Greek heroes often had to use cunning and trickery to secure their victories, e.g. Polyphemis, the son of Poseidon was tricked by Odysseus, who told him his name was 'No one'.
5. Zeus was Ruler of the Gods, Hera was his wife, and Poseidon – God of the Sea – was his brother. Zeus was also the 'Protector' of travellers.	6. Characters often appear in disguise, e.g. Odysseus dresses as an old beggar, and his wife and son don't recognise him, but a housemaid does. Aegeus only recognises his long-lost son Perseus by his sword.

7. Characters have 'destinies'; Perseus' grandfather King Acrisius was told he would be killed by his grandson, so he had Perseus' mother Danae imprisoned in a tower in an attempt to stop her having children.	8. Greeks didn't imagine a 'heavenly afterlife'; thinking that death would be boring. They aimed to do glorious deeds that would be remembered after they had died, so they could be celebrated.
9. Penelope – Odysseus' wife – stayed faithful to her husband all the time he was away. Odysseus had relationships with other women.	10. While Athena supported Odysseus, Poseidon tried to stop him from being successful because Odysseus had blinded his son, the Cyclops Polyphemis.
11. Theseus was left by his father, King Aegeus, when he was a baby. Their eventual reunion brought them both joy.	12. Some heroes were given weapons and special magical gifts by gods; e.g. Perseus was loaned a 'Cap of Darkness' which made him invisible.
13. The Greeks believed the Gods lived on Mount Olympus, whose summit was hidden by clouds, and therefore mysterious.	14. Demi-gods were the offspring of human women and gods who had visited the earth in human form.
15. The Greeks organised 'Olympic Games' in ancient times.	16. Many characters were sent on long journeys or 'quests'.
17. Baby girls were not valued in the same way as boys. Often they would be abandoned to die at birth.	18. 'Ambrosia' was the name given to the 'food of the gods'.
19. Many of the creatures Heracles had to kill were monstrous versions of common or domestic animals, e.g. flesh-eating horses, a golden stag, a three-headed dog etc.	20. Heracles was brave and strong, but could mistreat women. He killed Hippolyta after Hera had caused suspicion and conflict in their relationship and dealings with each other's armies.

21. In 'The Odyssey', there is a sea monster called Charybdis who created a whirlpool that wrecked ships.	22. The Hydra had many heads, and two would grow for every one cut off. Heracles killed it by searing each severed neck with hot metal, and cutting off and burying the immortal head.
23. Medea was Theseus' step-mother. She was jealous of him, and tried to trick his own father into killing him with poison.	24. Heracles killed the giant Enceladus and buried him under Mount Vesuvius, where he continued to 'breathe fire'.
25. Atalanta was a great huntress and female athlete. She had been abandoned as a baby, but survived and was raised by a she-bear. Aphrodite (goddess of love) helped Menalion to win her in marriage.	26. Odysseus' men succumbed to the Lotus Eaters, an island race which made travellers eat narcotic flowers, causing them to sleep and forget their quest, and thereby putting them in great danger.
27. The author JK Rowling was a student of Classic Greek culture.	28. The Coen Brothers' 2000 film 'O Brother Where Art Thou' is set in 1930s America, but uses 'The Odyssey' as its source material.
29. Classical architecture, literature and philosophy are evident in buildings, landscapes and theatres throughout the major cities of the western world.	30. Percy Jackson is a character in a series of children's books and films; he is the demi-god son of Poseidon.

Sports Vs Library

Sport helps students to develop teamwork and social skills, this will help them in adult life.

1

Doctors have found that regular physical exercise and activity will counteract stress and depression.

2

Skills in strategic thinking and motor skills improve with participation in sport; this can help with e.g. maths and problem solving.

3

More trophies in tournaments and competitions will boost a school's status and success. Everyone would benefit from belonging to a popular school that is known for winning.

4

The Education Standards Research Team have found that "there is a positive relationship between reading frequency, reading enjoyment and attainment". More choice of library books will help students to develop in this way.

5

Research reports a link between library use and reading for pleasure; young people that use their library are nearly twice as likely to be reading outside of class every day, and this will help their grades.

6

Children who start to play and enjoy sports are more likely to continue in adult life, and this will lead to improved health and happiness.

7

Students involved in sports are less likely to take drugs or smoke because they realize the impact that these destructive activities can have upon their performance.

8

The successful and acclaimed author Margaret Atwood says "reading actually makes you smarter, as neurological activity during the act of reading increases." That is, it makes the brain work more effectively.

9

The Qualifications and Curriculum Authority's PE and School Sport (PESS) investigation concluded that physical activity has a motivational impact on children, increasing their self-esteem and general wellbeing.

10

A leading ICT expert says that 'Children are fascinated by pressing buttons and making things work. Using appropriate technology provides opportunities to develop independent learning skills.' A new ICT suite that can be made available to children of all ages would be an asset to the school and the community.

11

Adolescence can be an emotional and difficult time; sport can create a positive body image and this will boost the confidence and self esteem of the shy and lonely children.

12

The school has a newly decorated lobby which could house an attractive trophy cabinet.

13

The school had a particularly successful athletics team in the 1990s.

14

Educationalists insist that technology is now such an important part of children's everyday lives that a learning environment without it would be completely out of touch with their own realities. More available and up to date ICT in the school will help to provide this.

15

Evidence suggests that reading for pleasure is an activity that has emotional and social consequences. Access to reading books can boost confidence and the ability of students to relate to each other, as well as grades.

16

Research as shown that having access to ICT resources and having books of their own has an impact on children's attainment. There is a positive relationship between the estimated number of books that are available and success in school.

17

Research shows that school sports can lead to "the acquisition and accumulation of various personal, social and socio-moral skills … can act as social capital to enable young people to function successfully (and acceptably) in a broad range of social situations" (Bailey, 2005).

18

An Academic Review from 2006 found that for young women, a sense of identity and empowerment can be gained through the development and achievement of physical skills.

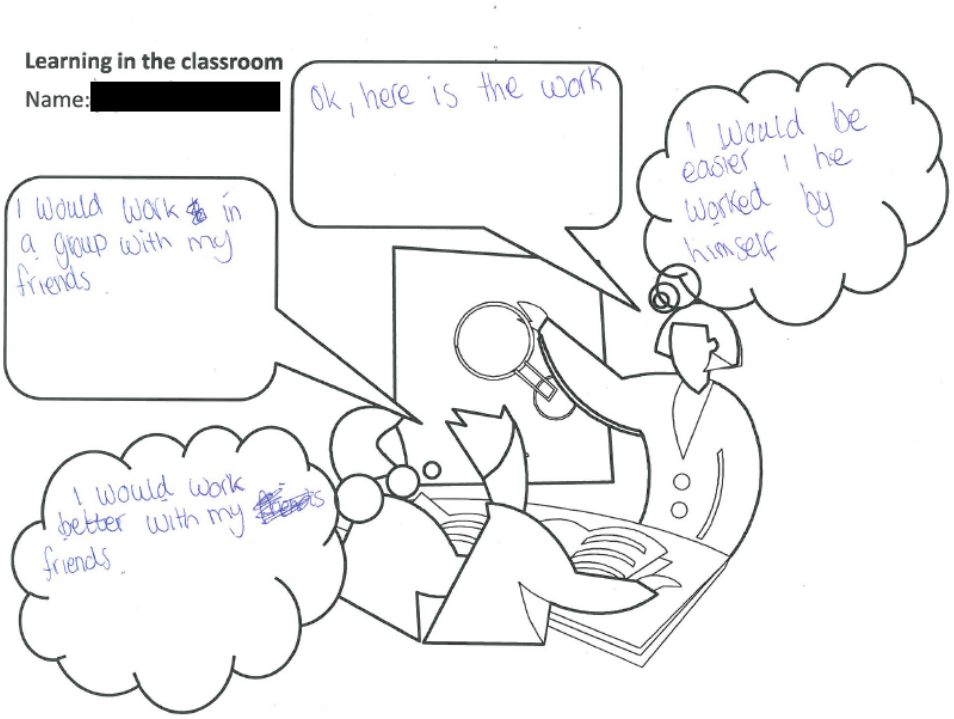
19

A number of studies have shown that boys enjoy reading less than girls; and that children from lower socio-economic backgrounds read less for enjoyment than children from more privileged social classes. The school should do as much as possible to ensure that children – especially boys – read for pleasure as much as possible.

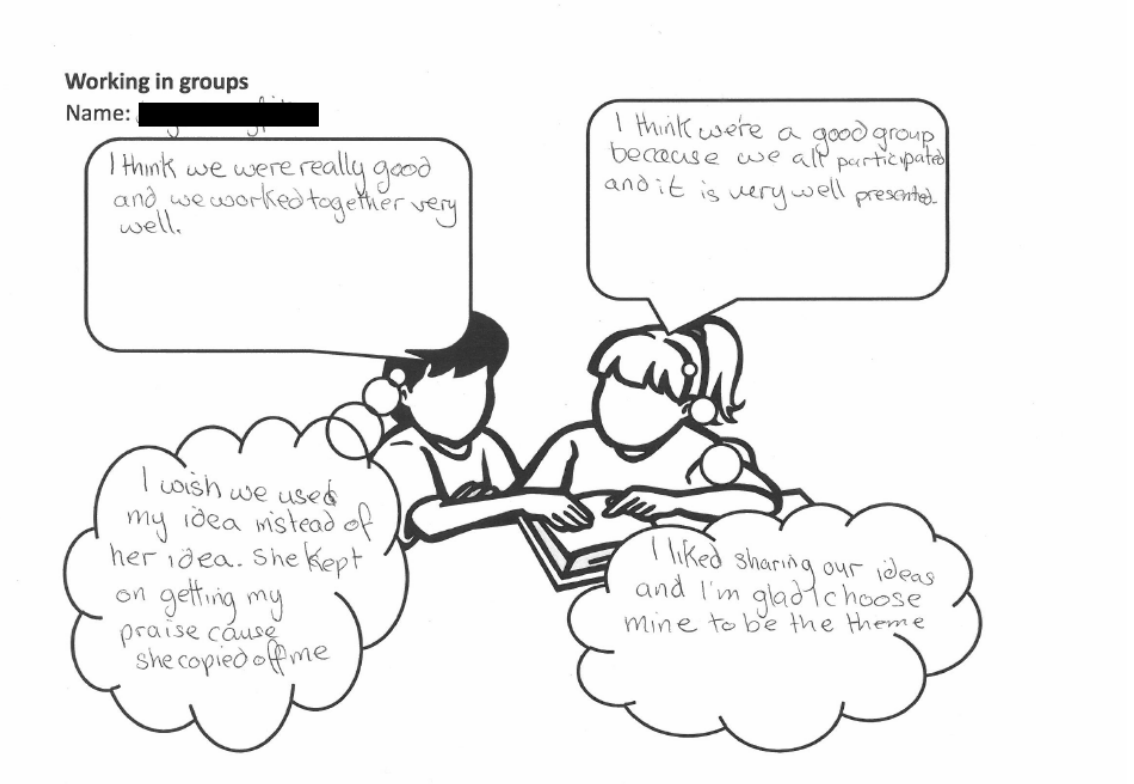
20

Appendix B: Example Pupil View Templates

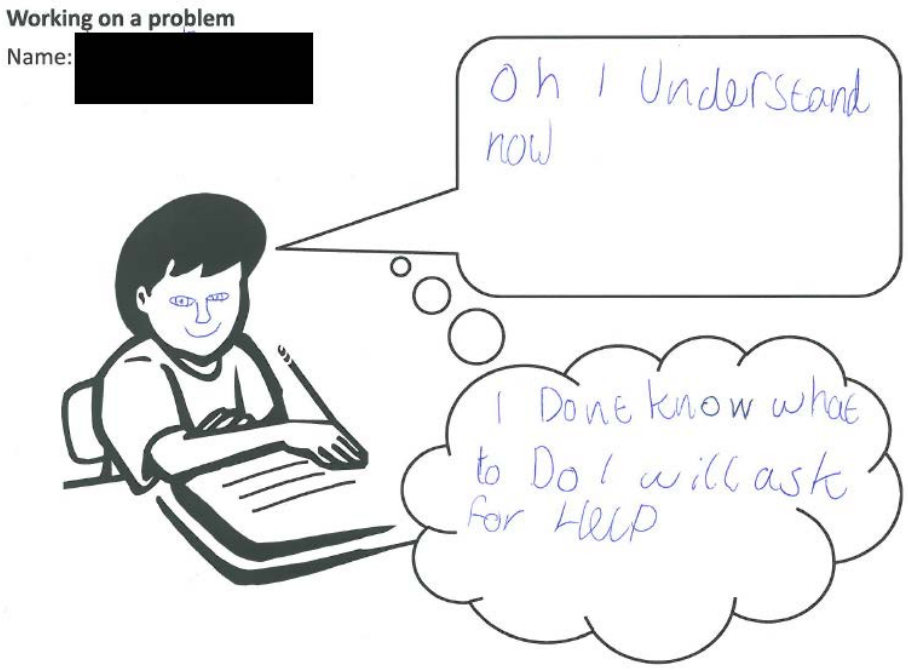
Learning in the Classroom



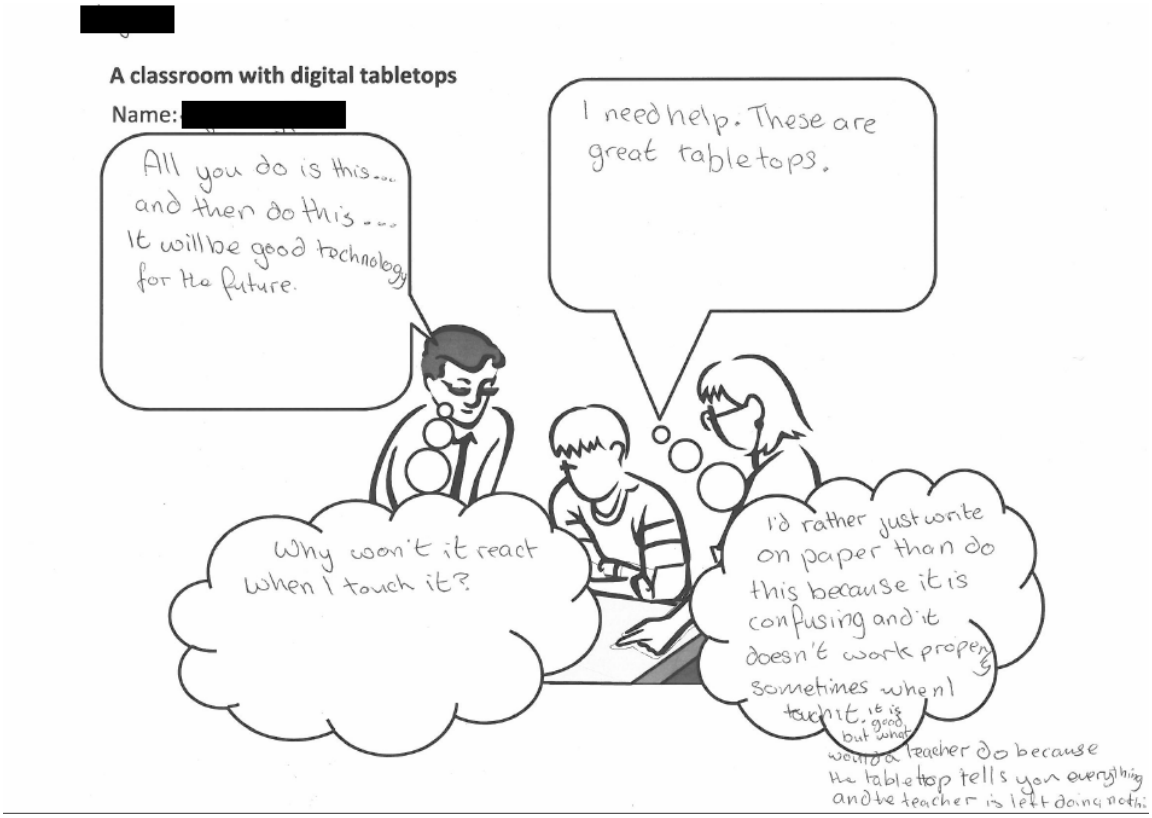
Working in Groups



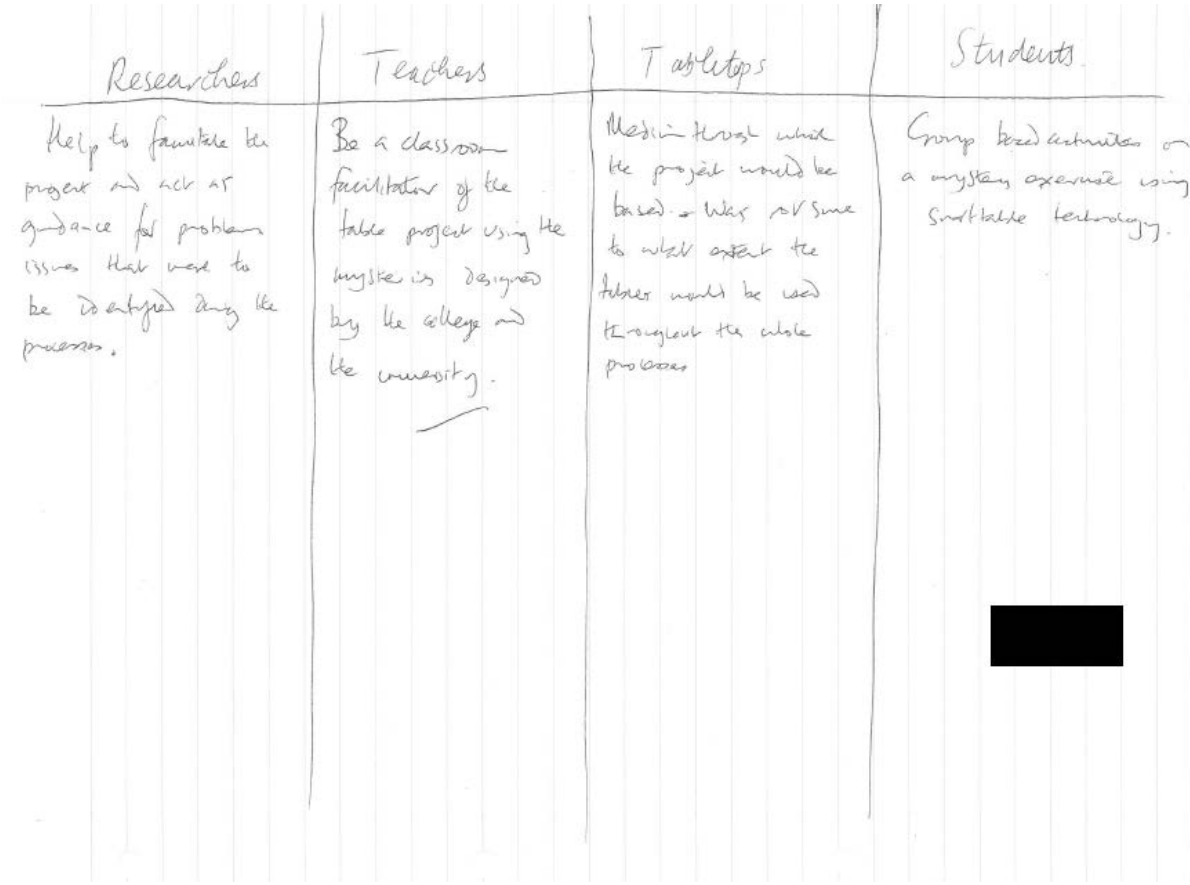
Working on a Problem



A Classroom with Digital Tabletops



Appendix C: Example Teacher Expectation Table



Researchers	Teachers	Tabletops	Students
Help to formulate the project and act as guidance for problem issues that need to be developed during the process.	Be a classroom facilitator of the tabletop project using the system as designed by the college and the university.	Mediation through which the project would be based - what or some to what extent the tabletop would be used throughout the whole process	Group based activities on a mystery exercise using smart table technology.

Appendix D: Example Teacher Plan

Class: 8.3D	**Number of students 30**		a c b a c Grand Total 2 30 **Current working level:**
Ability: Set 3 (High)	**M: 16**	**F: 14**	
SEN / G&T / LAC Pupils & Provision: **1 x EAL** **5x G+T** **1x LSR**			**End of Year Targets** c b a c Grand Total 0 30

Context	• Prior learning that will inform the learning that is planned. The class will be revisiting a topic from last term (Greek Mythology) and using their knowledge plus the 'Mysteries' ICT resource to create an extended piece of written work.
Content	• What they are going to learn (this could be statements from the specification / SOW) • How to plan and construct a proposal to persuade judges that their design for a library display/exhibition should be adopted to celebrate Ancient Greek culture. • Their work will be assessed for structure and cohesion (AF3 and AF4)
Where are they now?	• The class are secure level 6 for writing, but need to be stretched so that they are identifying and working towards level 7 skills for next year.
How do you know?	• Mark book/exercise books
Where are you trying to get them to?	• Literacy objective: successful use of connectives/discourse markers • AF3: Structure of texts • AF4: Effective paragraphing • AF2 Purpose (persuasive text)
How will you know they have arrived?	• Essay plan in lesson to be completed, peer and self-assessed and then the essay itself will be submitted for summative assessment

Lesson Phase	Assessment	Differentiation
Setting the Scene/ Big Picture **Class to review homework task, which was to 'mark' my exemplar essay on the earlier question 'Which character in MSND has the most power?' Check its level in AF3 and AF4 writing, and AF6 Reading. Use this to discuss the requirements of a level 7 piece of work, and to set personal targets for their written outcomes this week.**		**By outcome: class has been placed in random groups to work with the material.**
Input: Introducing and interacting with the new material Explain that the 'proposal' task introduced in the software last week has now been redefined as a **persuasive** text. There is a competition to decide which group's ideas should be adopted by the library, and so their proposal must be written in persuasive language. Recap the rules of persuasive language **(AFORESTEY)**	**'Thumbs up' exercise to ensure revision is successful.**	**By outcome**
Making Sense: Demonstrating understanding **Look at the questions posed in the task:** They had completed the 'reading' element of this task last week; students to look at the printout from each group's work and discuss (in groups) how they are going to use this material to inform the planning of the their proposal.	**Peer and self assessment**	**More able students to add statements/comments to those that already exist.**

Making Sense: Application of understanding Class to transfer to the ICT tables, and use the software in conjunction with the print outs from last lesson to produce a detailed plan that will generate a c400-500 word response from each student.	**Using the grouped statements, students to address the key question. Evaluate statements and organise them into an essay plan. NB: the software will instigate a 'reflection stage' before the task is complete**	**By outcome**
Review and next steps **Class Feedback. Each group to take it in turns to give ONE point from their plan that uses AFORESTEY to argue that their design should be adopted. Each group to vote for the point that they found the most persuasive. (You can't vote for your own group). Findings to be shared and 'taken on board' , plans to be adjusted if necessary.** **Explain that in tomorrow's lesson, each student will be typing up their proposal, and the word target will be 400-500 words.**		**By outcome**

Homework:
Students to look at http://www.bbc.co.uk/news/magazine-22972610 : a recent article about the revival of the ancient religion in modern day Greece. Some may use evidence from this to help to draft their proposal.

Co-operative Learning	**Thinking Tools**	**Habits of Mind**	**Communicating with Others**
Group work; collaboration using software	Mysteries	**Persistence; i.e. all statements must be read and considered**	

Include

- A copy of the class assessment record [photocopy of mark book] or a print out of progress review data, in colour!
- A seating for learning plan.
- IEP for individual pupils where appropriate
- Highlight pupils that are members of particular groups, such as: FSM; G&T;SEN; LAC.

Appendix E: Example Teacher Reflection

Reflection on the marking of the MSND essay/essay plan, and the Students' PMI/EBI analyses.

I'm about halfway through marking the class's exercise books and checking their writing, based on the printed out essay plans from last week's MSND reading exercise. I note the following:

As mentioned before, we need to make sure the reading stage has been completed carefully, and best use made of all the evidence. Some of the plans had very little detail in them, as the students hadn't retained the appropriate statements, and so far none have used quotation as evidence to support their conclusions.

They need more time to get used to the 'layout' of the plans, and establish where the 'connective' parts need to be placed in relation to the evidence and their own comments.

I think we need to be clear what the objectives are, by that I mean identify the reading and the writing objectives, as there is some overlap during the activities. If the students are going to benefit in as many ways as possible, they need to be more clearly informed as to what it is they're being asked to do.

As I'm marking the work, I find that I'm responding more to the points they're making with regard to the text, and then only afterwards to their construction of their essay. They are responding to the texts and coming up with some really interesting insights – e.g. Titania forces Oberon into extreme action by her intransigence. I feel we should incorporate this into the lesson plans at the initial reading stage, as it's a good opportunity to do so. (AF3 –interpretation; AF6- Writer's purpose; AF7 Cultural context etc.) We also need to factor in some practice writing PEE paragraphs so that we can cover a wider range of skills in the production of Extended Writing.

Maybe focus on the writing focusses on the follow up 'writing' stage?

I'd like to give them another go at this, as the written outcomes so far are disappointing. A few of them don't seem able to translate the work they've done on the tables into more than a couple of sentences; while these are sometimes well structured, more detail, a better writing technique and assurance in the way they express their ideas would be desirable.

The plans completed by Rachel, Amy and Sophie are worth looking at, as they so far suggest that the activity has helped them to construct more sophisticated responses to a challenging question.

A few more responses from the students to the software:

- *Leg room is an issue; a few want to be able to put their legs under the table.*
- *One thinks it would help teachers to be more organised.*
- *Another feels it's too small for everyone to use at once, and that they have to take turns to do each part of the task.*
- *One student wonders how easy/hard it would be to conduct the activity with only one member of staff present.*
- *A few like its novelty value.*
- *One girl described the same session as both 'stressful' and 'amazing'. I think that means she likes the technique but isn't yet comfortable with using it.*
- *The most negative statement came from a student who found that her group hadn't done a lot of work in 100 minutes, that the group had argued and she'd found it frustrating. This could have had a lot to do with the others she was working with, as they were not placed in friendship groups.*

Appendix F: Example Plus, Minus, Improvement

R-

Plus: these machines are very effective. writing up my essay I really improved my writing skills and structure of the text, I believe that this is down to writing up what our paragraphs are going to be about on the machines

Minus-Although these machines are very effective they are quite sensitive and at first abit hard to use

Intresting- they are diffrent and we would never had thought we could get a chance to use them . they helped alot to improve my work from a 5A to a 6A

L-

Plus- I think that these tables are really useful when it comes to planning long essays and it helps with improving levels because they can be very fun to use.

Minus- At times, these tables can be quite...broken...because sometimes they may not respond when clicking or maybe the calibration is sometimes a little off.

Interesting. I like these tables because they have helped me improve my levels quite a lot and I have enjoyed using them as well.

K-

Plus- the computers are extremely useful in multiple ways, and I'm really happy how all the plans we made came out after using this computer

Minus- After using this computer about five times, they can get boring and you feel as if you want to get out the room and get some fresh air

Interesting- After I used this computer as a plan, my structure level went up 2 sub-levels to a level 7b.

T-

Plus- I think these tables are very good for planning big essays and it also help with paragraph plans.

Minus- Sometimes the tables crash and are laggy and don't delete stuff.

Interesting- The sticky notes are good for linking, connectives, paragraphs and also the evidence it very very useful.

Appendix G: Example Marked Essay

English essay

We have to imagine our school has been awarded £500, 000. There are two proposals as to how the money could be spent; one is to expand the school library and ICT facilities, the other is to invest in improving sports and games equipment. In this essay I will debate for and against arguments for the two sides. I will outline good, bad points and finally say my personal opinion. What do you think is best- sports or books?

If we chose for it to be spent on sports it will benefit the pupils, parents, teachers and doctors will massively approve as it helps with peoples fitness. Having good physical education boosts children's self-esteem, there confidence and improves their fitness. Doctors have found that regular physical exercise and activity will counteract stress and depression. Adolescence can be an emotional and difficult time; sport can create a positive body image and this will boost the confidence and self-esteem of the shy and lonely children. Overall, sporting improves you physically, mentally but also helps you in the later life, e.g. sporting can get you a career in life. Sports is a win-win situation.

However, there are bad factors when improving the physical education side. As not all children enjoy participating in sports, don't feel confident and not themselves. Even though doctors say it boosts their confidences, strictly speaking it's not all true. Making children do more sports may make them feel less comfortable as they are forced to do things you don't want to do. Its making them less confident in themselves from making them show their bodies when not wanting to. Girls in particular; they may not be as active as others and there appearance will tend to be different. In-which puts girls off from doing sports. Also, sporting doesn't help you as much

as literature would for your career. Only a certain number achieve jobs from sporting. Whereas, a greater amount get jobs from English and literature.

On the other hand, if you put it towards the library and ICT it would help you from being an English teacher, to working in a shop. Research reports a link between library use and reading for pleasure; young people that use their library are nearly twice as likely to be reading outside of class every day, and this will help their grades. Evidence suggests that reading for pleasure is an activity that has emotional and social consequences. Access to reading books can boost confidence and the ability of students to relate to each other, as well as grades. People who prefer reading, ICT and literature then they would support this side.

Despite that, not supporting the sports will take away children from not having a little break, time to run about, have fun with their friends and perhaps a bit of competition with one another. Or some might look at it as children aren't getting enough exercise as they should, consequently they become over-weight. The children themselves, parents and also doctors would disapprove of the children becoming over-weight.

Over all, we believe sports is the way forward however, literature is just as important. Which is best? If it went to sports; children would become healthier, fitter and more confident. If it went towards the library and ICT; it would make a big impact in the long run. Students involved in sports are less likely to take drugs or smoke because they realize the impact that these destructive activities can have upon their performance. When focusing on literature they are twice as likely to achieve higher grades. I

personally think the money should be split between them both. This way everyone benefits and is happy.

Sophie Walton

AF3/4 - Your structure is excellent -
level 7c - I like your approach -
more is more challenge involved in
creating a balanced argument like
this, and you've integrated your
evidence very well.
You do need to look at the
clarity of your expression
(T) AF5 - sentence structure
AF6 - punctuation
- so that your meaning is
always clear.

Appendix H: Ethics

Ethical Assessment Form

Full Ethical Assessment Form

Newcastle University

APPLICATION FOR ETHICAL APPROVAL OF A RESEARCH PROJECT FROM FACULTY ETHICS COMMITTEE

This application form is to be used by **STAFF** and **PGR STUDENTS** seeking ethical approval for an individual research project where preliminary ethical assessment indicated full ethical review was required.

A completed version of this document should be emailed to the Secretary of your appropriate Faculty Ethics Committee in the University. *Applications must be completed on this form; attachments will not be accepted other than those requested on this form. This form has been designed to be completed electronically; no handwritten applications will be accepted.*

Research must NOT begin until approval has been received from the appropriate Faculty Ethics Committee.

SECTION 1: APPLICANT DETAILS

Name of Researcher (Applicant):	Philip Heslop
Email Address:	Philip.Heslop@ncl.ac.uk
Faculty & School:	**SAGE**
Contact Address:	**Space 2 culture lab, kings walk, Newcastle University, Newcastle-Upon-Tyne, NE1 7RU**
Telephone Number:	**0191 246 4629**

SECTION 2: PROJECT DETAILS

Project Title:	Collaborative Writing using a Digital Tabletop	
Name of Supervisor(s) (for PGR):	Patrick Olivier	
Is this project:	Internally Funded ☒	Externally Funded ☐
If externally funded, please provide the MyProjects BH reference number:		BH ☐☐☐☐☐☐
Category of Research:	Postgraduate Research ☒	Staff Research ☐

SECTION 3: TYPE OF PROJECT

Please indicate the predominant nature of this project (tick one box only):

Questionnaire/Survey e.g. surveys of members of particular groups / organisations; mail out questionnaires, street surveys	☐
Experiments	☒

e.g. participants completing tasks under controlled conditions, use of tasks/method other than or in addition to questionnaires/surveys	
Observational e.g. observing how people behave in a natural setting or in a laboratory	☐
Data-based e.g. the use of official statistics where individuals could be identified	☐
Other	☐
If you answered 'Other' please describe.	

SECTION 4: PROGRAMME STUDY DETAILS

Proposed date on which project or study will begin:	**July 2011**
Proposed date on which project or study will end:	**July 2013**

Project Outline & Aims:
Briefly describe the aims of this research as well as the main tasks (or tests) that participants will be required to complete or what use will be made of sensitive economic, social or personal data. This description must be in everyday language, free from jargon, technical terms or discipline-specific phrases.
(No more than 300 words)

The study is designed to assess the Collaborative Writing software on the Digital tabletop, and to ascertain the effect on students' structured writing. This study will address the following research question:

How can digital tabletop technologies support face-to-face collaboration and learning in the area of extended writing?

The study will involve students undertaking an initial exercise on a digital table and then (in a later session) using our Collaborative Writing research software as a structured writing tool to support their write-up of the initial exercise. The initial exercise will take between 30mins and 45mins and the writing exercise will take around 30mins. Both tasks completed by the students are collaborative

and will be completed using a promethean whiteboard and pens. After each group of students have completed the task they will complete a short semi-structured interview with the researcher. (Developing extended writing is a major school development focus).

The initial task and writing task are both collaborative table based tasks, using a promethean whiteboard and pens.

Each task will be video-recorded and the software will log the students' interactions with the digital tabletop. The video data will be subject to a qualitative analysis (thematic analysis) and the log data will be quantitatively analysed to identify interaction patterns (e.g. the subjects tend to do action X after theme Y has been discussed). The semi-structured interviews with students will be audio recorded. These audio recordings will be analysed using a qualitative, thematic analysis.

PROPOSED RESEARCH METHODS

Please provide an outline, in layman's terms, of the proposal research methods, including where and how data will be collected and stored, and all tasks that participants will be asked to complete. Specify if the research will take place outside of the UK or in collaboration with internationally-based partners, and/or if research will take place using the Internet. Present an outline of the method in a step-by-step chronological order, and avoid using jargon and technical terms as much as possible. (No more than 700 words)

The participants targeted for this study are in keystage 3 and aged between 13 and 14. The initial exercise and writing task will be conducted with groups of three to four students, with four to eight separate groups taking part (making 12 - 32 students overall). Participants will be selected by their teachers to take part in the study based on their overall academic ability. We aim to recruit both low achieving and high achieving groups.

The initial task will be a digital mysteries task, using the digital tabletop. The task involves reading and organizing data slips to answer a specific question and tests the higher order thinking skills of participants.

The writing task will also take place on the table. The same group will use the software to plan and write a persuasive document about their conclusion from the initial task. Since the writing task will occur at a different time from the initial task the participants will be able to view conclusion to the initial task before commencing.

Both the initial exercise and the writing task will take place in a classroom environment in a school under teacher supervision. They will be filmed on digital video cameras, and the interactions with the software will be logged. Log data will record the interactions with the software, e.g. "object 1 was moved 10 pixels left and 5 pixels right". Audio recordings of short interviews with participants will also be collected. This data will be stored on a university computer whilst analysis takes place, then it will be archived on a dvd or usb drive which will be stored in a locked cupboard or drawer. All data will be anonyomised before publication.

A thematic analysis will be applied to the video data and the log data will be used to identify potentially important interactions to guide the video analysis. Short semi-structured audio interviews will also be subject to a thematic analysis. Additionally, the final document produced by the writing task will be assessed anonymously by a teacher and compared with documents written without the software (from students with similar academic ability). It will be made clear to participants that assessment from this study is not part of their assessment within the school, and is for the purpose of the study only.

SECTION 5: PARTICIPANT DETAILS

Does this research specifically target (select all that apply):

Students or staff of this University	☐
Adults (over the age of 18 years and competent to give consent)	☐
Children/legal minors (anyone under the age of 18 years)	☒
The elderly	☐
People from non-English speaking backgrounds	☐
Welfare recipients	☐
Anyone who has a physical disability	☐
Clients of professionals	☐
Anyone who is a prisoner or parolee	☐
Any groups where a leader or council of elders may need to give consent on behalf of the participant	☐

Number of participants required:	**12 - 32**
Age from:	**13**
Age to:	**15**
Source and means by which participants are to be recruited:	**Schools will choose suitable pupils to take part in the study based on their academic record.**

Does this project require approval from an external authority (e.g. LEA, school, governing body)?	**YES** ☒	**NO** ☐
Has approval already been granted?	**YES** ☒	**NO** ☐

SECTION 6: PARTICIPANT INFORMATION	YES	NO
Will you inform participants that their participation is voluntary?	☒	☐
Will you inform participants that they may withdraw from the research at any time and for any reason?	☒	☐
Will you inform participants that their data will be treated with full confidentiality and that, if published, it will not be identifiable as theirs?	☒	☐
Will you provide an information sheet that will include the contact details of the researcher/team?	☒	☐
Will you obtain written consent for participation?	☒	☐
Will you debrief participants at the end of their participation (i.e., give them an explanation of the study and its aims and hypotheses)?	☒	☐
Will you provide participants with written debriefing (i.e., a sheet that they can keep that shows your contact details and explanations of the study)?	☒	☐
If using a questionnaire, will you give participants the option of omitting questions that they do not want to answer?	☐	☐
If an experiment, will you describe the main experimental procedures to participants in advance, so that they are informed about what to expect?	☒	☐
If the research is observational, will you ask participants for their consent to being observed?	☒	☐

SECTION 7: PARTICIPANT CONSENT

Please describe the arrangements you are making to inform participants, before providing consent, of what is involved in participating in your study:

Information sheets (attached) will be provided to the Schools outlining the scope of the research and the methods used; this will also be provided to the pupils before they give consent. In addition, these information sheets and a consent form supplied by the school will be sent home to parents to obtain their consent for their child's participation in the study. .

Please describe the arrangements you are making for participants to provide their full consent before data collection begins:

The Schools will obtain consent from both pupils and the parents to take part in the study, using the consent form included with this document. Before individual studies a researcher will ask subjects if they understand the process (by going through the information sheet with them), i.e. if they mind being filmed and interviewed, as well as inform them that they can leave the study at any time.

Participants will be told the full scope of the study, and that their work will be anonymously assessed at the end of the study. Any questions during the study will be answered as fully as possible.

Participants should be able to provide written consent. If you think gaining consent in this way is inappropriate for your project, then please explain how consent will be obtained and recorded.

SECTION 8: PARTICIPANT DEBRIEFING

Please describe the debriefing that participants will receive following the study and the exact point at which they will receive the debriefing:

Participants will be reminded about the scope of the study (by going through the attached debrief sheet), and that their work will be anonymously assessed (and that the assessment will not contribute to their grades). Any questions will be answered as fully as possible.

It is a researcher's obligation to ensure that all participants are fully informed of the aims and methodology of the project, and to ensure that participants do not experience any levels of stress,

discomfort, or unease following a research session. Also describe any particular provisions or debriefing procedures that will be in place to ensure participants feel respected and appreciated after they leave the study. Please attach the written debriefing sheet that you will give to participants. If you do not plan to provide a written debriefing sheet, please explain why.

SECTION 9: INSURANCE & RISK CONSIDERATIONS

The appropriate arrangements concerning insurance and/or indemnity to meet the potential legal liability of the University or other external funders for harm to participants arising from the management, design and conduct of this research will be confirmed by the University's Insurance section.

Potential risk to participants and risk management procedures

Identify, as far as possible, all potential risks (small and large) to participants (e.g. physical, psychological, etc.) that are associated with the proposed research. Please explain any risk management procedures that will be put in place and attach any risk assessments or other supporting documents.

Participants will be in an ordinary classroom environment, with full teacher supervision. The technology involved is a commercially available Digital Table, which is already in widespread use in classroom environments. Participants will be reassured that their work will not contribute to their school grades. The investigators will not be left alone with participants as their will be teacher supervision at all times.

Potential risk to researchers and risk management procedures

What are the potential risks to researchers themselves? For example, personal safety issues such as lone or out of normal hours working or visiting participants in their homes; travel arrangements, including overseas travel; and working in unfamiliar environments. Please explain any risk management procedures that will be put in place and attach any risk assessments or other supporting documents.

The investigators will not be left alone with participants as there will be teacher supervision at all times.

SECTION 10: SUPPORTING DOCUMENTATION

Please supply copies of any applicable documents in support of your answers. Ensure that attached files have appropriate file names.

Document	Attached
Participant Consent Form	☒
Participant Information Sheet	☒
Participant Debriefing Document	☒
Questionnaire(s)	☐
Outline Protocol	☒
Risk Assessment	☐
Others (please list):	

SECTION 11: DECLARATION

I certify that the information contained in this application is accurate. I have attempted to identify the risks that may arise in conducting this research and acknowledge my obligations and the rights of the participants.	
Name of Principal Investigator:	Philip Heslop
Signed:	
Date:	

If you have any queries on this form, please contact your Faculty Ethics Coordinator or visit the website at http://www.ncl.ac.uk/business-directorate/ethics/index.php

Please email or send this form to the appropriate Faculty Ethics Coordinator

For office use only:

The appropriate Ethics Committee has considered the ethical aspects of this proposal. The committee recommends that the programme/project be:

☒ Approved ☐ deferred (for reasons attached) ☐ not approved

Example Parental Consent Form

Dear Parent/Carer,

Your child has the opportunity to participate in a study carried out by Newcastle University.

The aim of the study is to find out how children's literacy skills can be improved by using an interactive table top writing frame. Your child's involvement in the project will be to work with Newcastle University staff at various stages in the table top development process.

Newcastle University hope to publish the findings of the study and to comply with the university ethics procedure need consent forms for students who have participated in the study. You can be assured that no student names will be used in the publication. The University have requested however that we get parental consent forms for photographs and video of participating students. As part of the study, video is taken of the project, and data is collected from the software. None of this data is used for assessment of your child and is only used to evaluate the software. All data collected is stored securely at Newcastle University and will not be used for any other purpose. I would be grateful therefore if you could sign and return the consent slip below. If you have any questions about your child's participation in the study please do not hesitate to contact me.

Yours sincerely,

Year Leader, Access Phase

To: Year Leader Access Phase

Name of Student: ……..

I give permission for my child's participation in a study by Newcastle University to be referred to in any published findings from the study.

I give permission for my child's photograph to be used by Newcastle University in relation to the study.

Signature of Parent/Carer ……

Date: ……..

Example Participant Information Sheet

Thank you for volunteering to take part in this study. To complete the study I'm going to ask you to do two things. First, to complete a digital mysteries task, and then, later, write about the digital mysteries task. In both tasks you will work with two or three other students on a digital tabletop.

In the digital mysteries task you will be asked to solve a problem with two or three other students using information provided on the digital tabletop.

In the second task you will write an explanation of your solution to the problem again with two or three other students. I will be there throughout both tasks to help you work with the digital tabletop and tell you in more detail about the tasks. Your involvement in this study is important because it will help me to understand how a digital tabletop can support collaborative writing. This study is not being used by the school to assess you. Only your anonymous group written answer will be looked at by a teacher to evaluate the writing process. Your group's written answer will not be used for grading purposes.

The sessions will be filmed and your interactions with the digital tabletop will be collected. If you do not wish to have these details recorded please let me know and I will end the study. All of this data will be stored safely at the university and will be used only to understand how a digital tabletop can support collaborative writing.

If you have any questions, please feel free to ask at any time. If you wish to leave the study, you are free to do so at any time. If you decide to leave the study at any time your data will be deleted and will not be used.

Example Participant Debrief

Thank you for participating in the study.

The purpose of the Study was to help me to understand how a digital tabletop can support collaborative writing, or writing in groups.

The second part of the study where you wrote about the mystery will be analysed and assessed so that I can determine how the digital tabletop may have helped with the writing task. After the writing task I talked with you for a short time about what you thought about the writing stage and the design of the technology. None of this information will be used by the school to grade you, and my analysis of the data I collected throughout this study will be completed anonymously. For example, I will not link your name to any images of you.

If you have any questions about the study, then please feel free to ask them.